FIFTH TRI-SERVICE SYMPOSIUM ON EXPLOSIVES TESTING

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DAHLGREN DIVISION
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SILVER SPRING, MD

14 - 15 APRIL 1993

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OBSERVATIONS ON SCALING THE SIZE OF GAP TESTS

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FIFTH TRI-SERVICE SYMPOSIUM ON EXPLOSIVE TESTING

APRIL 15, 1993

OBSERVATIONS ON SCALING THE SIZE OF GAP TESTS

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ABSTRACT

The parameters which influence the experimentally determined shock sensitivity of an energetic material are discussed. The results of Foan and Coley and other literature data are used to illustrate the importance of the pressure-time loading on the acceptor in defining a 50% point. It is recommended that a common gap test system be adopted. A possible system, based upon the NSWC ELSGT, is proposed. Some preliminary data are presented showing the potential usefulness of such a system. Numerical simulation of the pressure-time shock loadings for various sizes of donor and attenuator in a gap test provide valuable insight into how test results (50% points) can be dictated by the donor configuration.

BACKGROUND

- IMPORTANT PARAMETERS IN MEASURING THE SHOCK SENSITIVITY OF AN ENERGETIC MATERIAL INCLUDE:
  - THE PRESSURE-TIME LOADING PROVIDED TO THE ENERGETIC MATERIAL (EM)
  - THE DIMENSIONS AND CONFINEMENT OF THE ENERGETIC MATERIAL
  - THE SHOCK REACTIVITY OF THE ENERGETIC MATERIAL

- IT IS DESIRABLE TO KNOW BOTH THE PRESSURE AND THE PRESSURE-TIME LOADING AT THE END OF THE GAP AT THE 50% POINT.

SHOCK SENSITIVITY TESTS

* NOL LARGE SCALE GAP TEST (LSGT)
  NOL MODIFIED GAP TEST (MGT)
* LANL WEDGE TEST
* LANL LARGE SCALE GAP TEST
* UK LANI TEST
  (LOW AMPLITUDE SHOCK INITIATION)
* AFATL SUPER GAP TEST (SGT)
* NSWC EXPANDED LSGT (ELSGT)
* NWC AQUARIUM GAP TEST
* NSWC AQUARIUM GAP TEST

SHOCK REACTIVITY VS. SHOCK SENSITIVITY

- THE LASL WEDGE TEST PROVIDES A MEASURE OF SHOCK REACTIVITY WHILE THE LASL LARGE SCALE GAP TEST IS A MEASURE OF SHOCK SENSITIVITY OF AN ENERGETIC MATERIAL.

- IT IS EXTREMELY USEFUL TO HAVE KNOWLEDGE OF BOTH THE SHOCK REACTIVITY AND SHOCK SENSITIVITY. SHOCK REACTIVITY SHOULD BE INDEPENDENT OF THE TEST ARRANGEMENT WHILE SHOCK SENSITIVITY IS VERY DEPENDENT ON THE TEST ARRANGEMENT.

DONOR/GAP CHARACTERISTICS

- PRESSURE - TIME LOADING
    - PRESSURE
    - SHOCK DURATION
    - INFLUENCED BY THE ASPECT RATIO OF DONOR (DIAMETER/HEIGHT), DONOR LENGTH, ETC.

"SHOCK INITIATION IN GAP TEST CONFIGURATIONS"

G.C.W. FOAN & G.D. COLEY

- USED A MODIFIED GAP ARRANGEMENT WITH UNCONFINED ACCEPTORS AND A WITNESS BLOCK

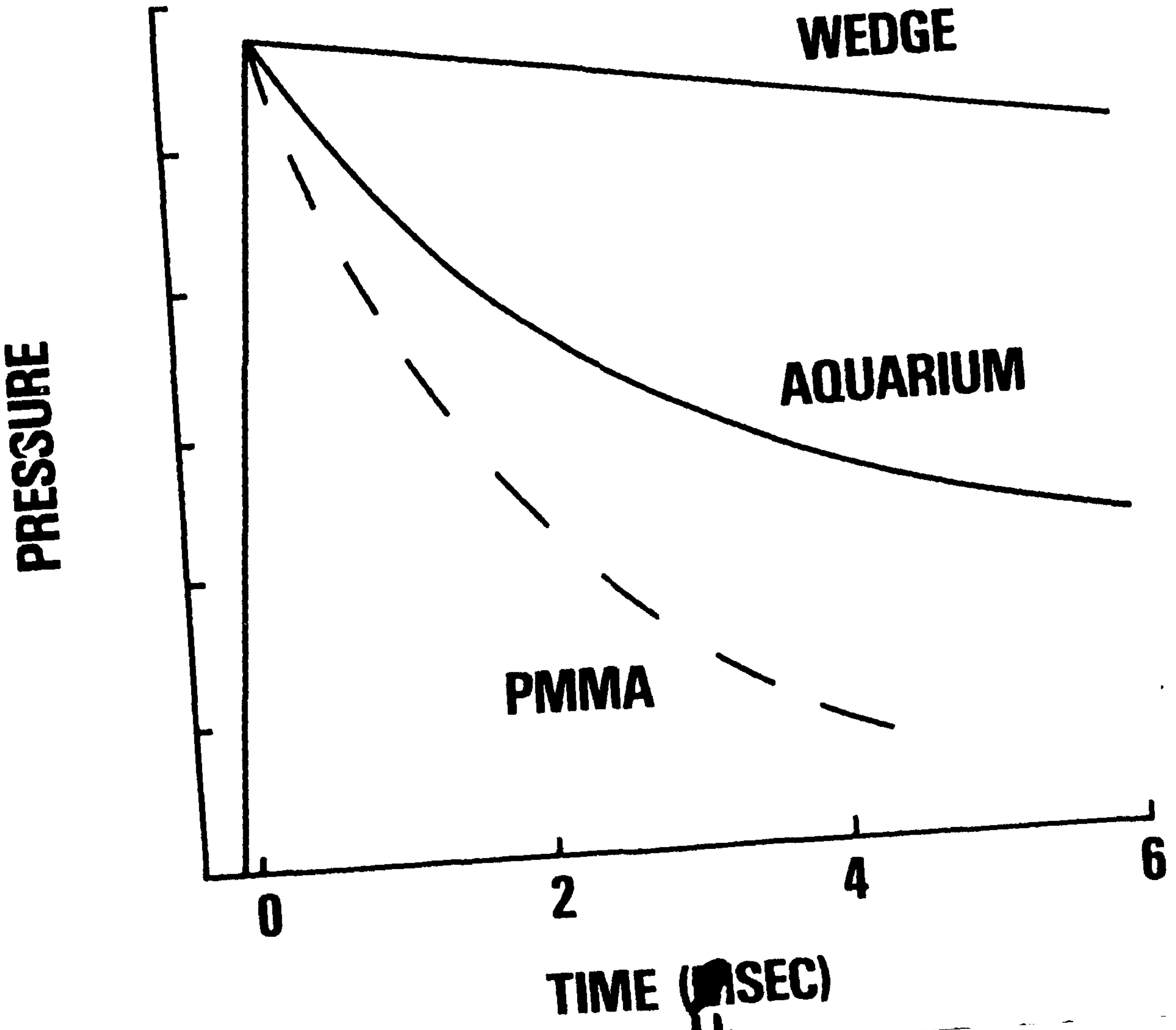
- DONORS:
  - COMPOSITION B
  - BARATOL
  - HMX/POLYETHYLENE

- ACCEPTORS (PRESSED):
  - TNT - 1.60 Mg/m^3
  - PETN - 1.67 Mg/m^3
  - TATB/Kel-F - 1.91 Mg/m^3

- VARIED DIAMETER OF DONORS AND ACCEPTORS

- USED PIEZO-RESISTIVE GAGES TO MEASURE P - T LOADING PRESENTED TO ACCEPTOR

PRESSURE-TIME CHARACTERISTICS OF EXPERIMENTAL ARRANGEMENTS



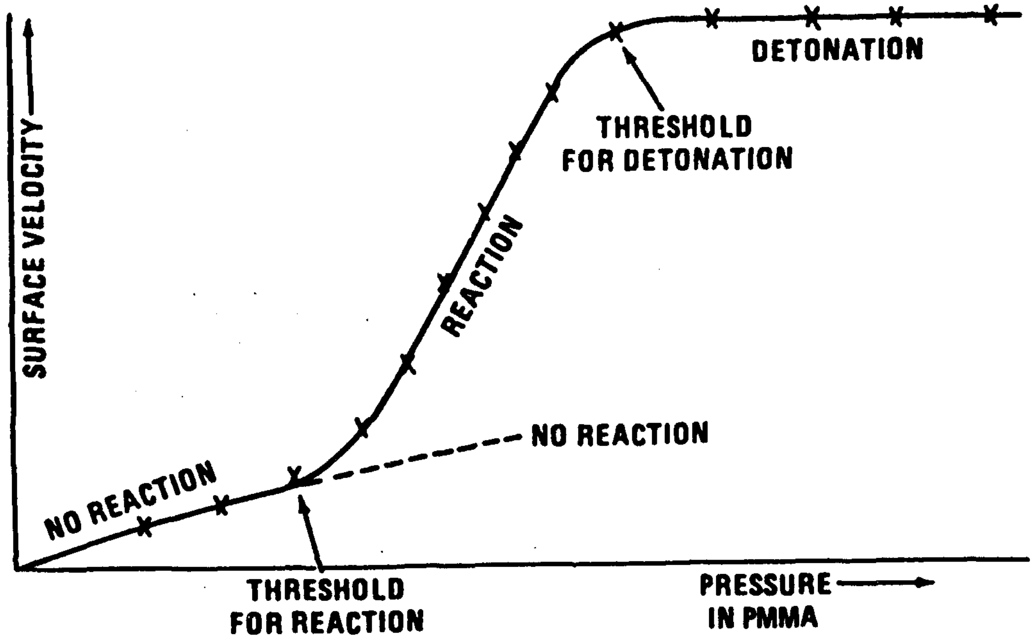


Fig. 5. Typical LASI Test Results.

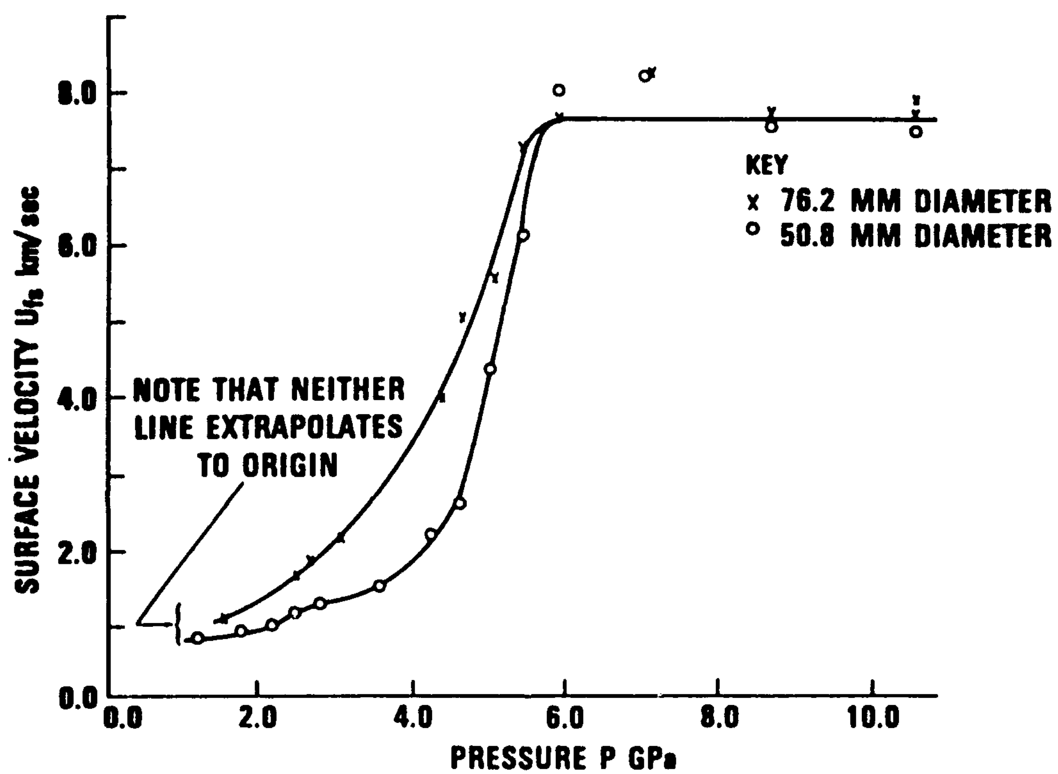
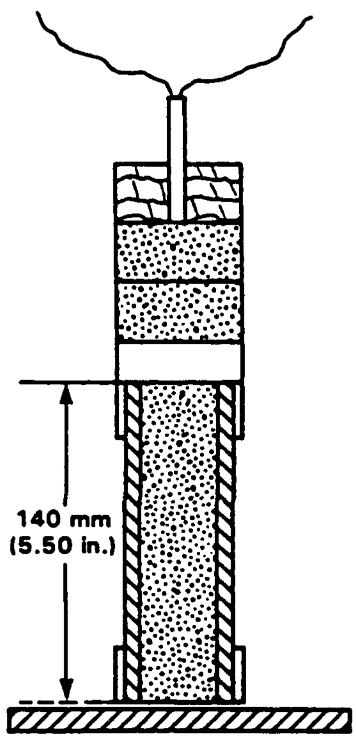
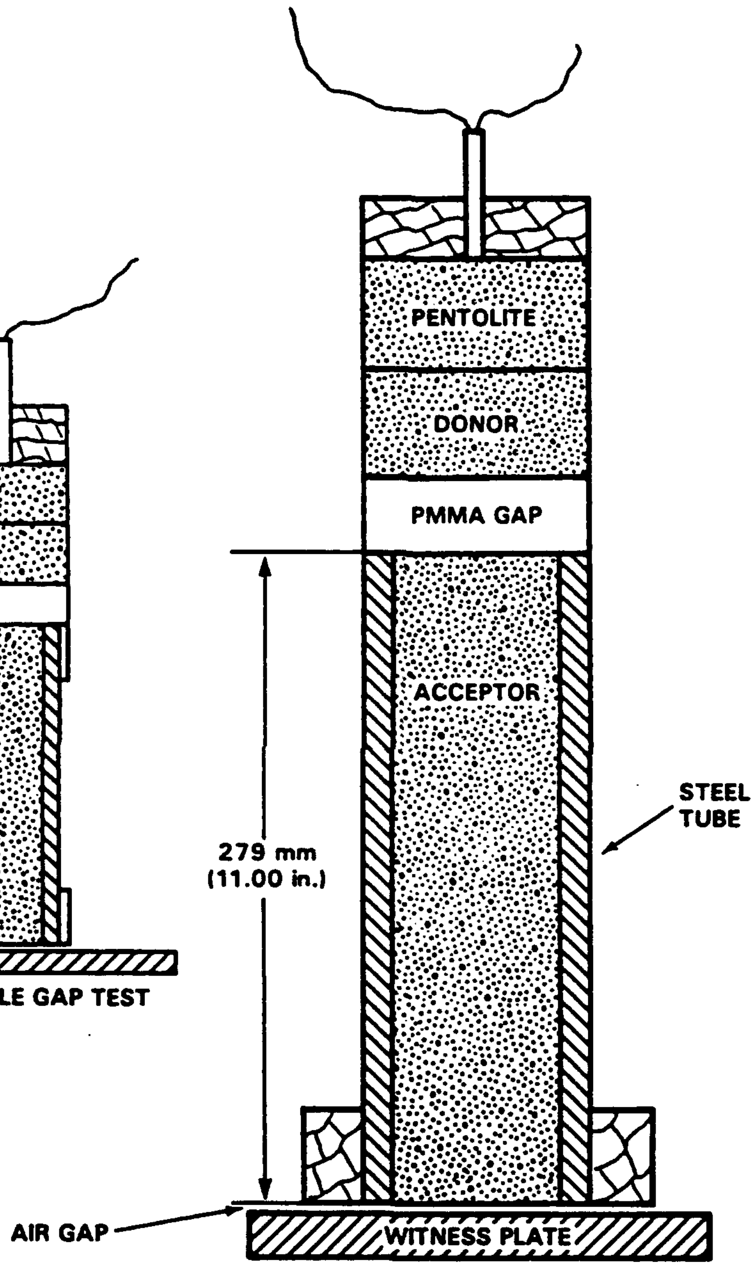


Fig. 13. Results for RDX/Polyurethane 80:20, ρ_o = 1503 kg/m^3 for Two Diameters.



LARGE SCALE GAP TEST



EXPANDED LARGE SCALE GAP TEST

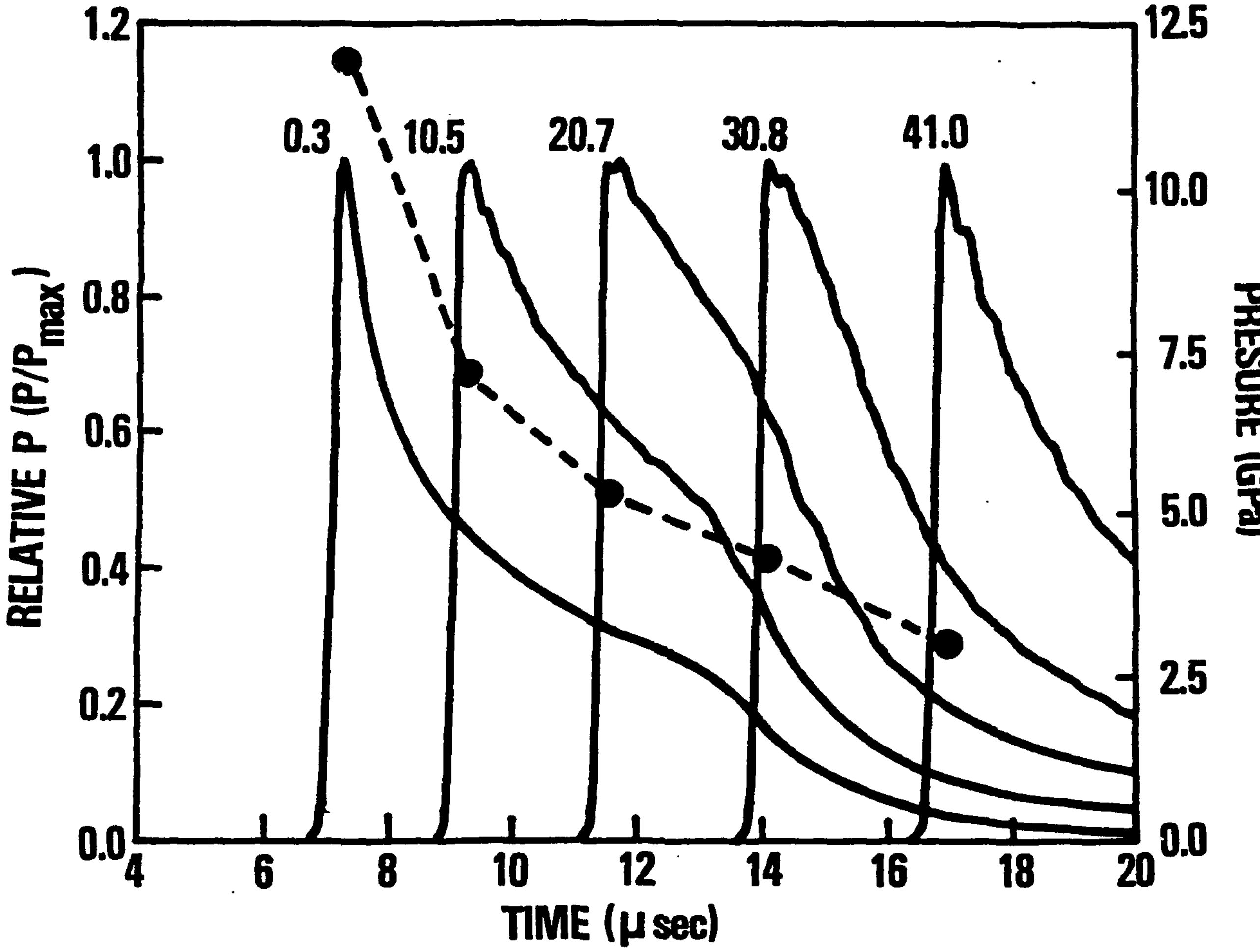
MODELING PENTOLITE DONORS IN AQUARIUM EXPERIMENTS

H. STERNBERG

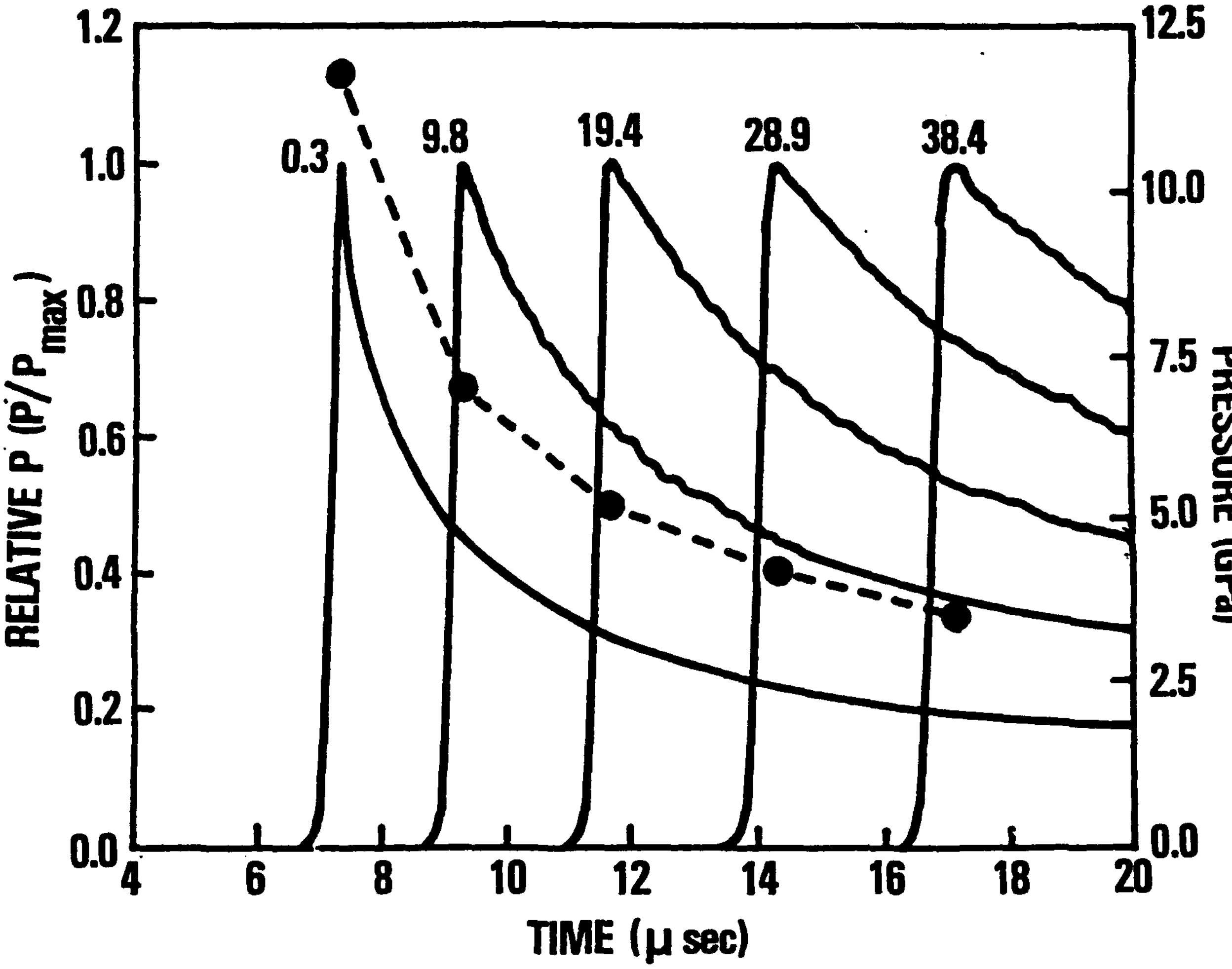
L. HUDSON

S. JACOBS

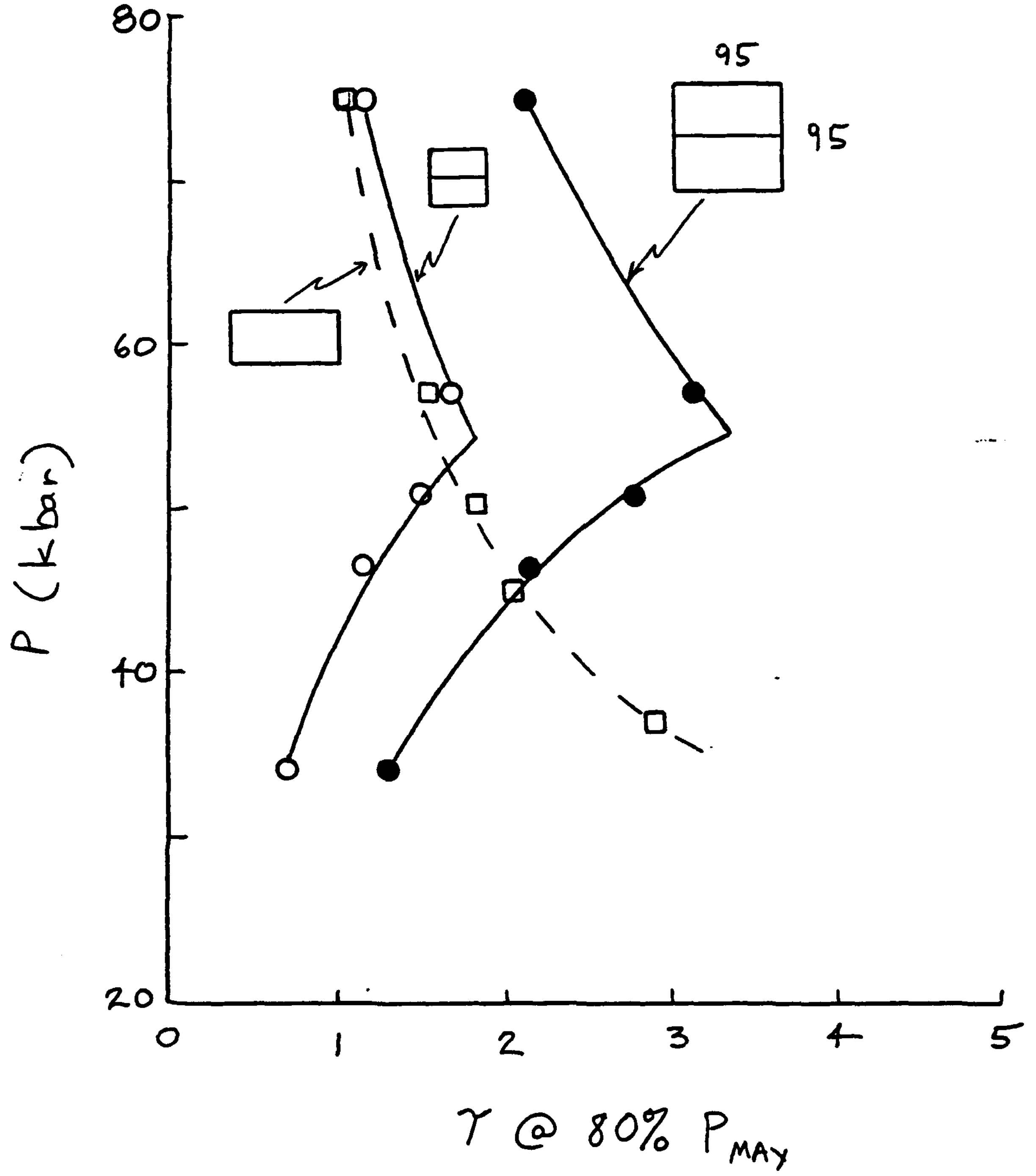
R. BERNECKER



PRESSURE—TIME DATA FOR VARIOUS LOCATIONS ON AXIS FOR 5.0 CM HIGH X 5.0 CM DIAMETER DONOR (D/H = 1). (NUMBERS ARE LOCATIONS IN MM FROM DONOR; ● P_{max})



PRESSURE–TIME DATA FOR VARIOUS LOCATIONS ON AXIS FOR 5.0 CM HIGH X 10.0 CM DIAMETER DONOR (D/H = 2). (NUMBERS ARE LOCATIONS IN MM FROM DONOR; ● P_{max})



80
60
40
20
P (kbar)
0
1
2
3
4
5
95
95
γ @ 80% P_MAX

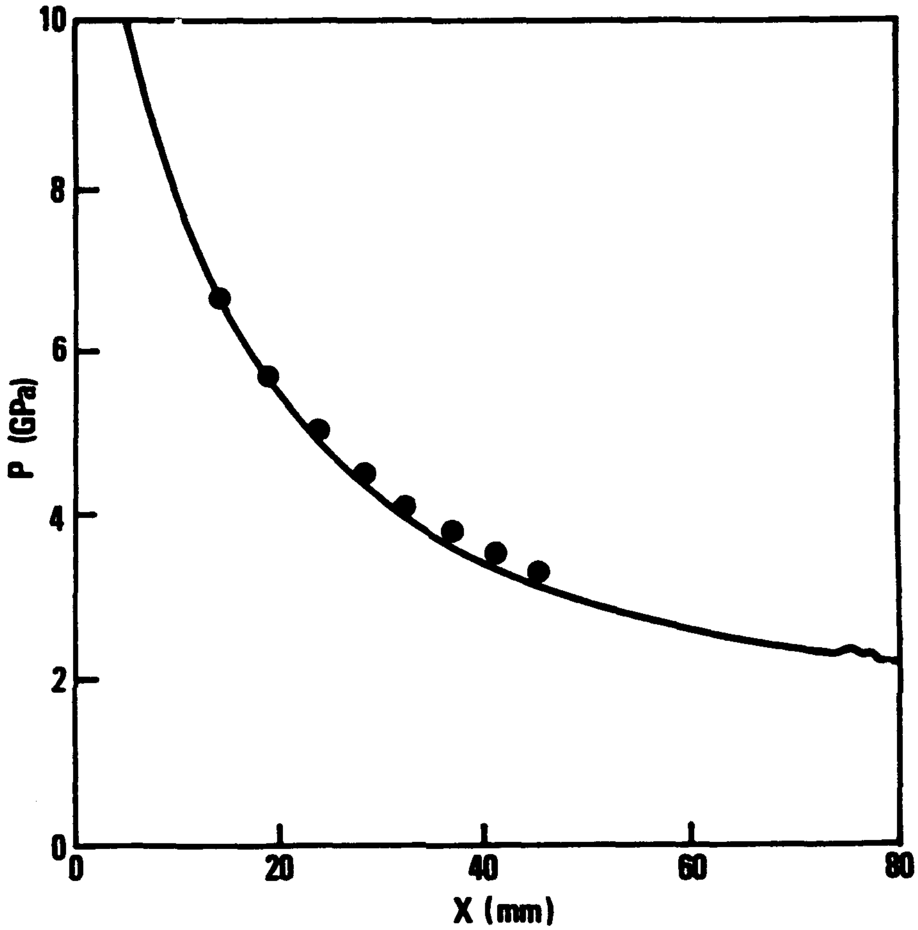
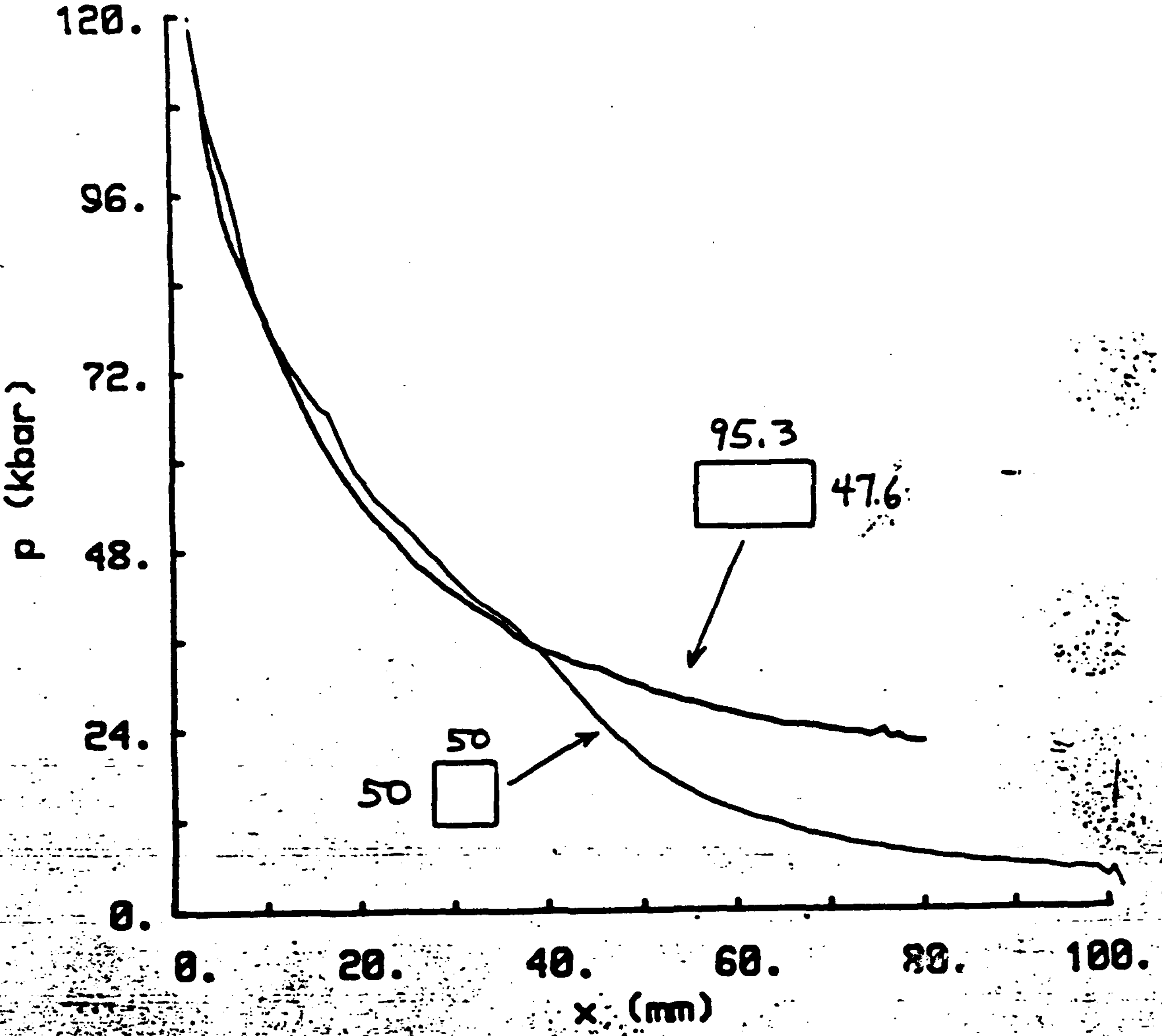


FIGURE 4. VARIATION OF PRESSURE WITH DISTANCE FOR DONOR C, 4.765 CM HIGH X 9.53 CM DIAMETER, IN WATER. (● HUDSON—STERNBERG CALCULATIONS)


120.
96.
72.
48.
24.
0.
p (kbar)
0.
20.
40.
60.
80.
100.
x (mm)
95.3
47.6
50
50

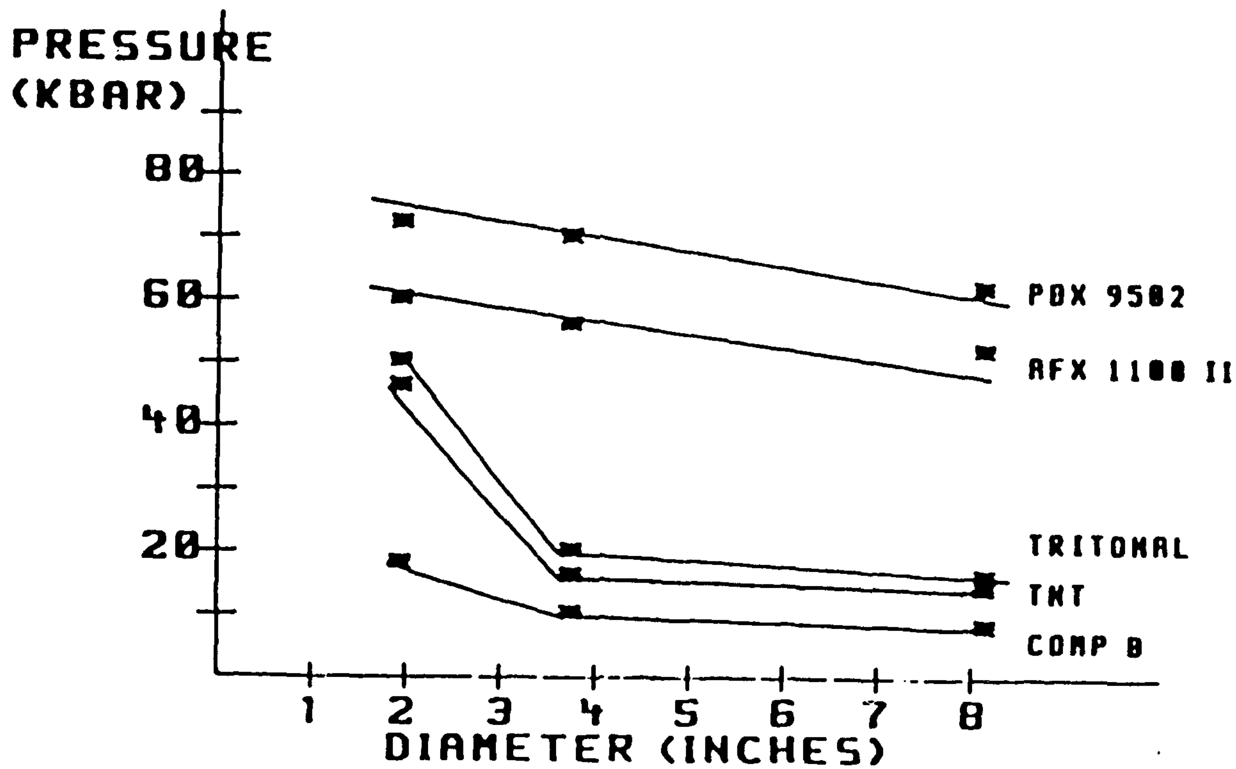
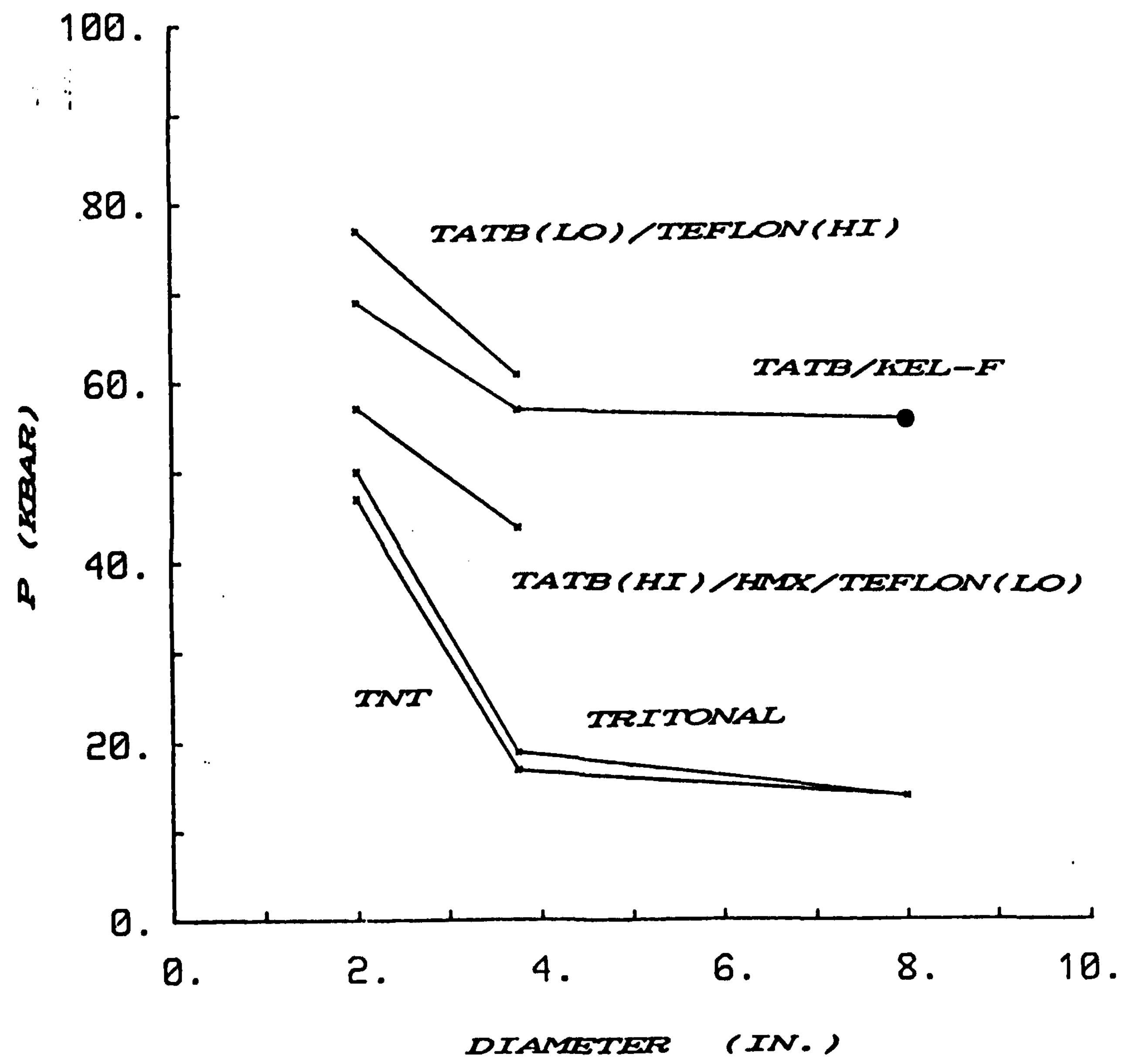


FIGURE 8. GAP TEST COMPARISON OF
PRESSURE VS DIAMETER



TATB(LO)/TEFLON(HI)
TATB/KEL-F
TATB(HI)/HMX/TEFLON(LO)
TNT
TRITONAL
P (KBAR)
DIAMETER (IN.)
100.
80.
60.
40.
20.
0.
2.
4.
6.
8.
10.

RECOMMENDATIONS

- USE THE DONOR/ATTENUATOR SYSTEM OF THE ELSGT AS EXTENSIVELY AS POSSIBLE FOR SHOCK TESTING OF INSENSITIVE EMs.
- REDESIGN THE ACCEPTOR OF THE ELSGT FOR A "SMALL SCALE" SHOCK SENSITIVITY TEST.
- USE THE LATERALLY CONFINED DONOR AFATL SGT (SUPER GAP TEST) AS A "LARGE SCALE" SHOCK SENSITIVITY TEST FOR THE EXTREMELY INSENSITIVE EMs.

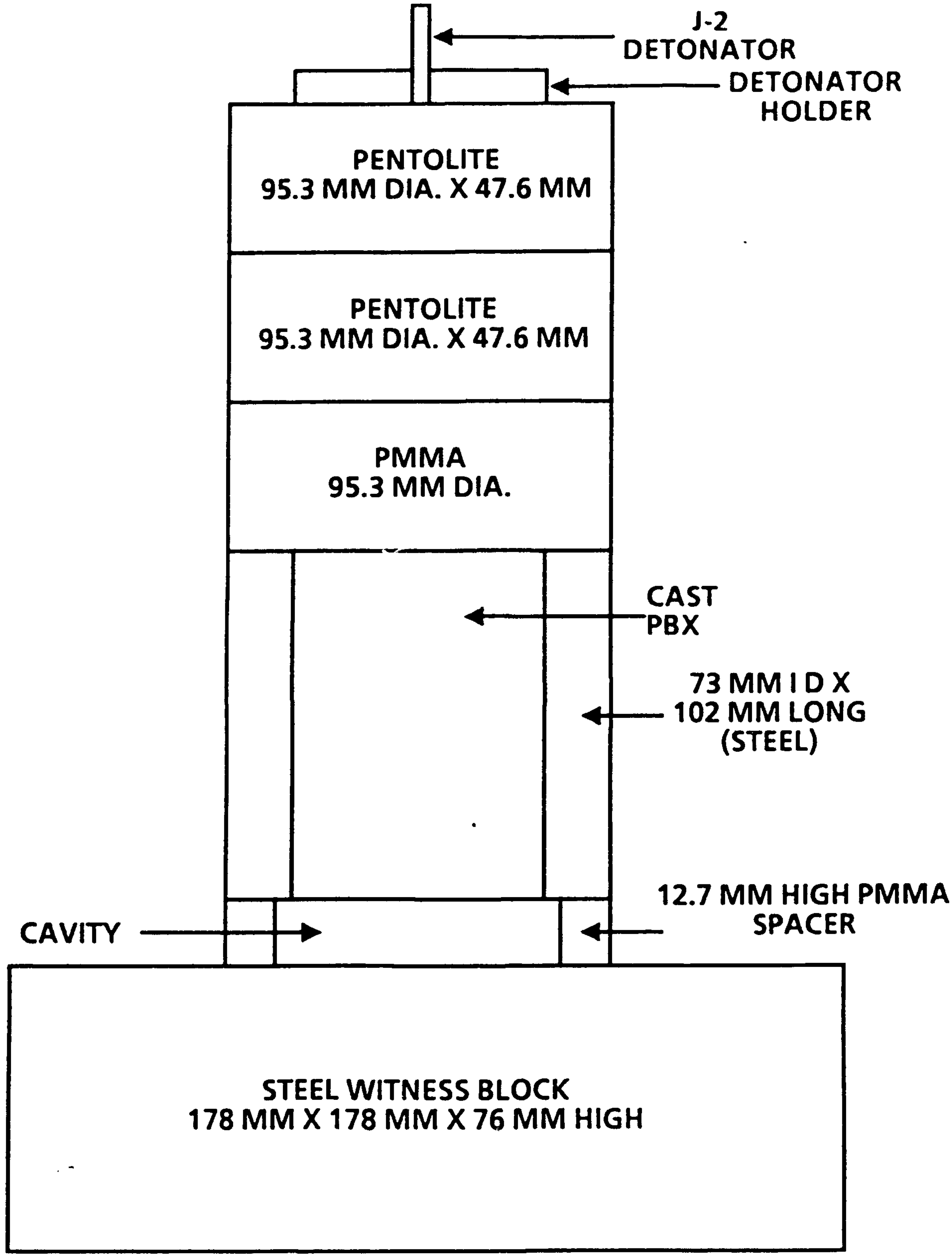


FIGURE 5. CURRENT CONFIGURATION OF IMAD GAP TEST.

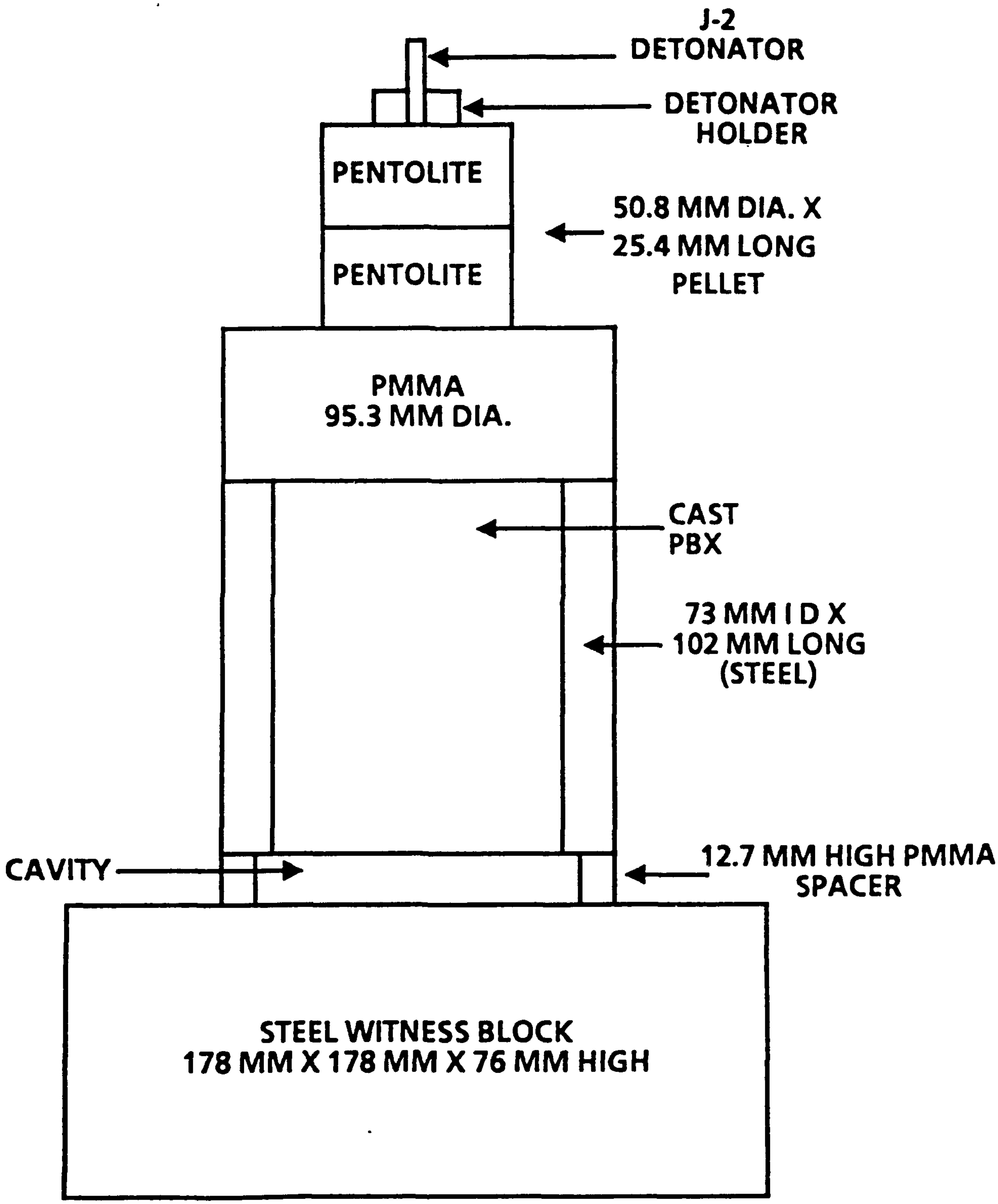


FIGURE 7. IMAD GAP TEST CONFIGURATION TO EVALUATE EFFECT OF SHOCK DURATION.

VARIABLE CONFINEMENT COOKOFF TEST OF METAL ACCELERATING EXPLOSIVES

By
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ABSTRACT

The Variable Confinement Cookoff Test (VCCT) was developed as a means of predicting the response of an ordnance item subjected to slow cookoff conditions using a laboratory scale explosive sample and test fixture. A one-inch diameter explosive sample of approximately 60 grams is placed in an aluminum sleeve surrounded by a steel sleeve of desired thickness. The sample is heated at 3.3°C per hour until a reaction occurs. The test is repeated using a steel confinement of increased thickness until a reaction greater than a burn is witnessed. The thickness at which this occurs correlates to a confinement burst pressure and is used as a means of predicting the slow cookoff response of the composition in a large munition. The paper will describe the VCCT results and will provide a comparison of the slow cookoff results of the same explosives in the 3.2-inch generic shaped charge.

INTRODUCTION

As part of the Naval Sea Systems Command (NAVSEA) Insensitive Munitions Advanced Development (IMAD) Program, High-Explosives (HE) Project, the Metal Accelerating Task is designed to develop and test high performance explosive formulations for fragmenting warheads, shaped-charge designs, and submunitions. Advanced compositions undergo performance, vulnerability, and safety testing, and the data gathered from these tests is used to select the most promising compositions which are later qualified for future Navy use.

During the development of new compositions, binder and energetic ingredients are often either in short supply or costly because they are limited to low volume production. Also, a substantial amount of time is required to properly develop a procedure that is suitable for loading generic or large-scale hardware. As a means of lowering the cost and time to evaluate new formulations, a screening test called the variable confinement cookoff test (VCCT) was developed. The VCCT is a small scale test designed to evaluate the response of explosive samples when subjected to slow cookoff (SCO) conditions. The test uses 1-inch diameter by 2.5-inch long explosive billets encased in a variety of steel confinements to establish the confinement pressure that causes the explosive to transition from a burning reaction to a reaction more violent than a burn under SCO heating conditions.

The VCCT allows prescreening of the most promising formulations before a large investment in time and materials is incurred. The test is also useful in evaluating the effects of changes in a formulation; for example, increasing or decreasing the energetic component, and using the test results as a means of predicting the response in larger generic hardware. This paper will discuss the results of evaluating several compositions and the results of testing the same formulations in the 3.2-inch generic shaped charge test unit (GSCTU).

CONFINEMENT PRESSURE OF THE 3.2-INCH GSCTU AND THE VCCT

During FY 90, SCO tests of several metal accelerating explosives were conducted using the 3.2-inch GSCTU. During the tests, the initiator housing was easily expelled by the pressure buildup caused by the explosive. Analysis showed that the four screws holding the initiator assembly failed when the internal pressure of the warhead reached approximately 200 psi. Consequently, all of the explosives passed the test due to the light confinement of the warhead. To increase the confinement pressure of the warhead, the initiator housing was redesigned with 12 larger retaining screws. (Analysis of the Shoulder-Launched Medium-Range Assault Weapon (SMAW), a warhead similar in size to the 3.2-inch GSCTU, showed that the initiator was expelled at approximately 3500 psi.)) The redesigned initiator was experimentally determined to fail at an internal pressure of approximately 4000 psi. However, during actual hydrostatic burst pressure testing of the redesigned 3.2-inch GSCTU, it was found that the copper liner failed before the initiator was expelled. The maximum pressure that was measured was 925 psi, at which point the copper liner collapsed, allowing the internal pressure to quickly fall to 0 psi.

The explosives previously tested in the original design were retested using the 12 retaining screw design. The results showed a variety of reactions, from burning to detonation.

The confinement pressure of an explosive has a direct bearing on the results of SCO testing. To better understand the VCCT fixture, it was decided to determine the confinement pressure at failure for each sleeve thickness. This was done using static calculations based on the yield strength of the steel sleeves and was determined experimentally during hydrostatic burst pressure tests. The calculations compared closely with the actual experimental tests. The results of the experimental tests are found in Table 1. Note that during burst pressure testing, it was noticed that the aluminum sleeve failed within the steel sleeve prior to reaching the full failure pressure of the steel sleeve. Hence, the pressures listed in Table 1 are the pressures required to burst the steel sleeve, independent of the presence of the aluminum sleeve.

TABLE 1. MEASURED VCCT HYDROSTATIC BURST PRESSURES

STEEL WALL THICKNESS (INCHES)	CONFINEMENT PRESSURE (PSI)
0.000	1200*
0.015	2350
0.030	5230
0.045	7725
0.060	10000
0.075	12700
0.090	15300**

*Aluminum sleeve without steel confinement sleeve
**Calculated

VARIABLE CONFINEMENT COOKOFF TEST

Test Description

The test procedure begins with loading the aluminum sleeve with the explosive under study. For pressed compositions, this is accomplished by pressing three, 1-inch diameter by 0.833-inch long, pellets at the highest percentage of TMD possible and sliding the pellets into an aluminum tube. In the case of cast explosive compositions, the material is cast directly in the aluminum tube and allowed to cure. The hardware and charge are assembled as shown in Figure 1. During assembly, the explosive-filled aluminum tube is slid into a steel sleeve with the confinement pressure determined by the thickness of the sleeve. The explosive sample is tightened securely between two witness plates to preclude its exudation or venting.

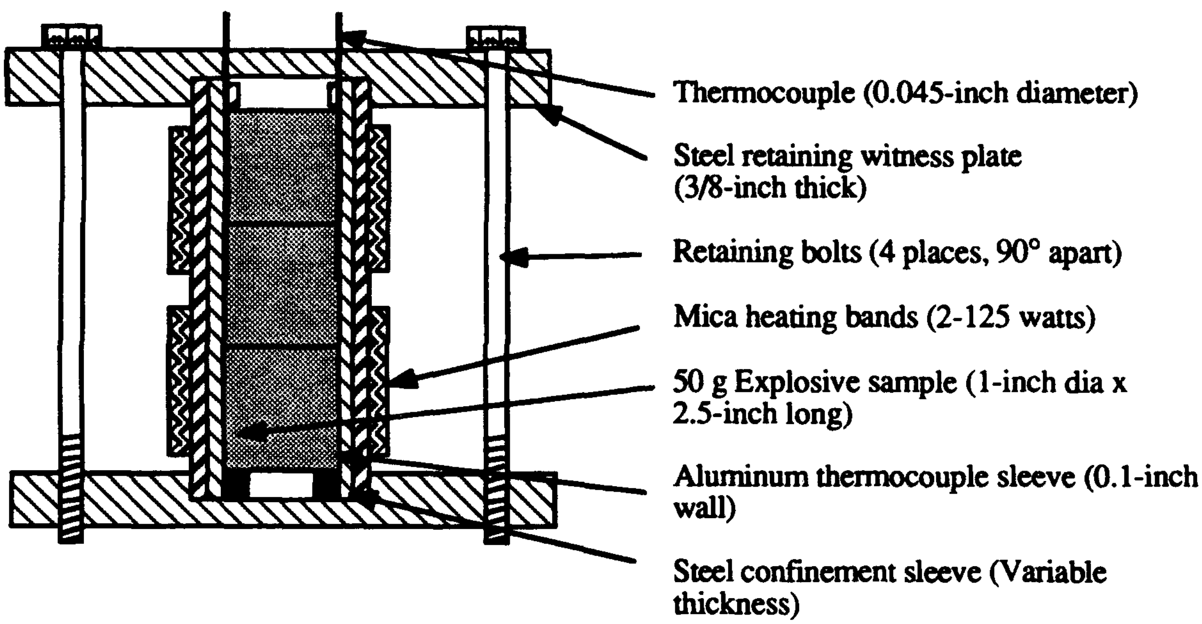

FIGURE 1. ASSEMBLED VARIABLE CONFINEMENT COOKOFF TEST DEVICE

The test was conducted by heating the sample at the specified rate of 3.3°C per hour until a reaction occurred. Duplicate testing was conducted at each confinement, and the confinement was increased in increments of 0.015-inch until a reaction more violent than a burn was noted. The confinement pressure at which each explosive transitioned to a reaction level greater than a burn is shown in Figure 2. Formulation and performance information concerning the explosives that were tested can be found in Tables 2 and 3, respectively.

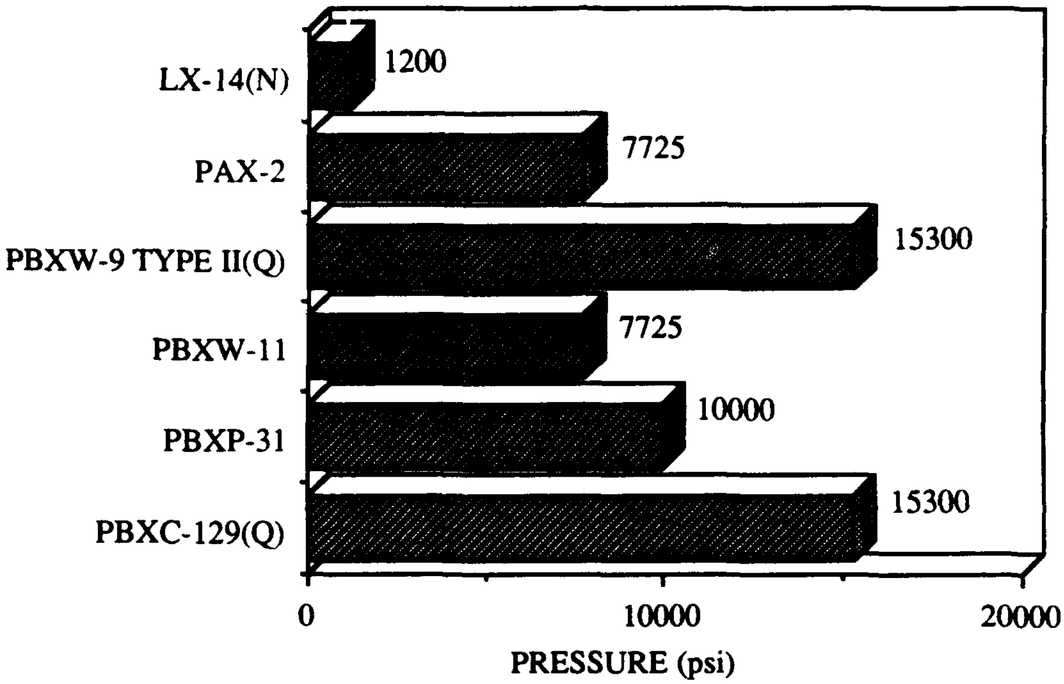

FIGURE 2. LOWEST PRESSURE AT WHICH A REACTION GREATER THAN A BURN OCCURRED

TABLE 2. CANDIDATE METAL ACCELERATING EXPLOSIVES

FORMULATION	BINDER	WEIGHT PERCENT	EXPLOSIVE	WEIGHT PERCENT	DEVELOPER
LX-14(N)	Estane	4.5	HMX	95.5	LLNL[1]
PAX-2	NP/CAB	12/8	HMX	80	ARDEC[2]
PBXW-9 TYPE II(Q)	DOA/Hycar	6/2	HMX	92	NSWCDD
PBXW-11	DOA/Hycar	3/1	HMX	96	NSWCDD
PBXP-31	Silicone	4	HMX	96	MBB[3]
PBXC-129(Q)	LMA	11	HMX	89	NAWCWD[4]

[1]Lawrence Livermore National Laboratory
[2]Army Research and Development Engineering Command
[3]Messerschmitt Boelkow Blohm
[4]Naval Air Warfare Center Weapons Division, China Lake, California

TABLE 3. METAL ACCELERATING EXPLOSIVE CHARACTERISTICS

EXPLOSIVE FORMULATION	DENSITY(g/cc) TMD	DENSITY(g/cc) NOMINAL	DETONATION PRESSURE (kbar)	DETONATION VELOCITY (mm/μsec)	GURNEY CONSTANT (5mm/19mm)
LX-14(N)	1.85	1.82	351**	8.83	2.30/2.95
PAX-2	1.74	1.73	300**	8.35	----/2.85
PBXW-9	1.76	1.73	296	8.49	2.58/2.90
PBXW-11	1.83	1.80	342**	TBD	TBD
PBXP-31	1.83	1.82	330**	8.56	N/A
PBXC-129(Q)	1.72	1.72	307**	8.37	TBD

*Theoretical Maximum Density
**Calculated

Comparison of VCCT and SCO Results

A comparison of SCO test results in the 3.2-inch GSCTU and VCCT are found in Table 4. As seen, VCCT testing of LX-14 required the lowest confinement pressure of the candidates to induce a violent reaction. In this example, only the aluminum sleeve was used and the reaction level witnessed was a detonation. LX-14 also demonstrated a detonation reaction in the 3.2-inch GSCTU, the most violent reaction witnessed among the candidates shown. PBXW-9 and PBXC-129 required the highest confinement pressure among the candidates to induce a deflagration reaction in the VCCT. By comparison, PBXW-9 demonstrated a burning reaction in the 3.2-inch

GSCTU. (PBXC-129 was not tested in the 3.2-inch GSCTU but was tested in the naturally-fragmenting test unit (NFTU). A mild burning reaction was witnessed in the NFTU (explosive weight approximately 35 lb). Based on these results, it is predicted that PBXC-129 would have demonstrated similar results as PBXW-9 in the 3.2-inch GSCTU.)

Also note that PBXW-11 passed SCO testing in the 3.2-inch GSCTU and reacted more violently than a burn at 0.045" steel confinement. This follows the expected trend (lower steel confinement required to cause a violent reaction) since PBXW-11 has a higher percentage of HMX as compared to PBXW-9.

TABLE 4. COMPARISON OF 3.2-INCH GSCTU AND VCCT SLOW COOKOFF RESULTS

EXPLOSIVE	3.2-INCH GSCTU SLOW COOKOFF RESULTS	VCCT STEEL CONFINEMENT IN INCHES AND PSI
LX-14(N)	DETONATION	0.000, 1200
PAX-2	EXPLOSION	0.045, 7725
PBXW-9 TYPE II(Q)	BURN	0.090, 15300
PBXW-11	BURN	0.045, 7725
PBXP-31	PARTIAL DETONATION	0.060, 10000
PBXC-129(Q)	BURN	0.090, 15300

Although the data discussed above showed some agreement in the results of VCCT and 3.2-inch GSCTU testing, some conflicting results were also observed. For example, using PBXW-11 as a baseline, it demonstrated a burning reaction in the 3.2-inch GSCTU and transitioned to a reaction level above a burning reaction at 0.045" steel confinement. PBXP-31 testing resulted in a partial detonation in the 3.2-inch GSCTU yet did not transition to a reaction level higher than a burn in the VCCT until tested at 0.060". Similarly, PAX-2 transitioned to a reaction level higher than a burn at the same confinement level in the VCCT as PBXW-11, yet explosion reactions were witnessed during duplicate testing in the 3.2-inch GSCTU.

Several conclusions can be drawn from the tests completed thus far. First, the VCCT was able to show trends as the energetic component of a similar composition (same binder) was increased. This is seen by comparing the results of PBXW-9 (92% HMX) and PBXW-11 (96% HMX). Second, the most violent (LX-14) and least violent (PBXW-9 and PBXC-129) reactions to SCO in the 3.2-inch GSCTU exhibited the same tendency in the VCCT. Of all the candidates tested, PBXP-31 clearly contradicted the general trend by passing the VCCT at 0.045" steel confinement, but partially detonated in the 3.2-inch GSCTU. PAX-2 also did not follow the trend where it failed at 0.045" steel confinement (the same failure point as PBXW-11), but exploded in the 3.2-inch GSCTU. It is well known that the type and percentage of energetic ingredient, the type of binder used, the charge size, and the confinement of the charge all influence the results of SCO testing. In the case of PBXP-31, the binder system was silicon based, different from the carbon based binders of the other explosives tested. Similarily for PAX-2, an energetic binder system was used, significantly different than the inert binder systems used in the other explosives. It could be surmised that the charge size had a larger influence on SCO testing of PBXP-31 and PAX-2 than the other explosives tested.

CONCLUSION

In conclusion, the VCCT does have merit as a screening tool and may provide useful insight as to the behavior of a formulation in SCO testing in generic scale hardware. However, to develop confidence in the test as a predictive screening tool, further characterization and testing of explosives in the VCCT will need to be completed. From the limited data to date, the selection criterion would be that new metal accelerating explosive formulations must pass the VCCT at 0.030-inch steel confinement to be selected for testing in the 3.2-inch GSCTU. But until additional testing of the VCCT is complete, restrictions like this will not be implemented.

IMADHE

IMAD METAL ACCELERATING TASK

VARIABLE CONFINEMENT COOKOFF TEST

STEVE COLLIGNON

APRIL 15, 1993

METAL ACCELERATING EXPLOSIVES

OBJECTIVE

- DEVELOP, EVALUATE, AND QUALIFY HIGH PERFORMANCE EXPLOSIVES FOR FRAGMENTING WARHEADS, SHAPED CHARGE DESIGNS, AND SUBMUNITIONS

TEST PROGRAM FOR SHAPED CHARGE EXPLOSIVES

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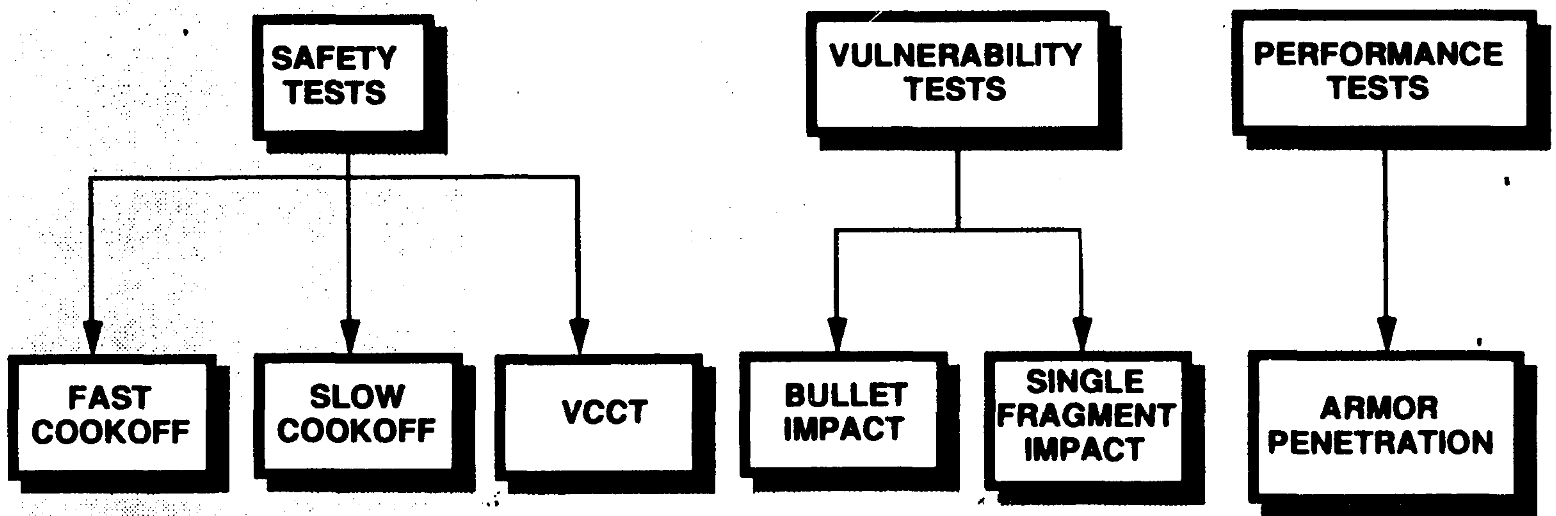
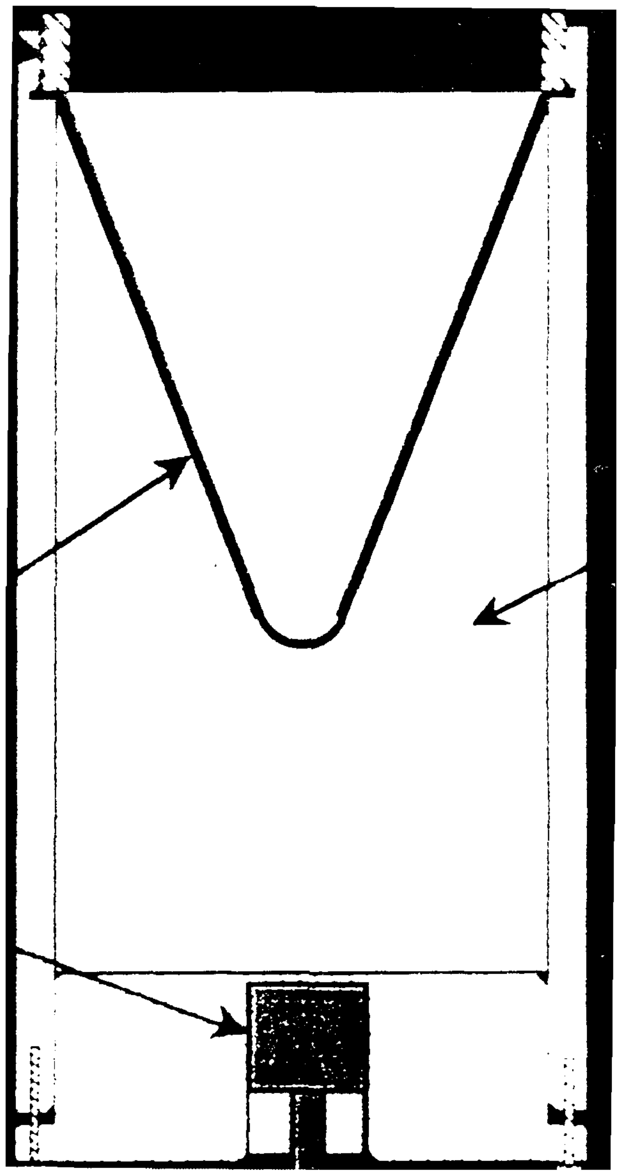
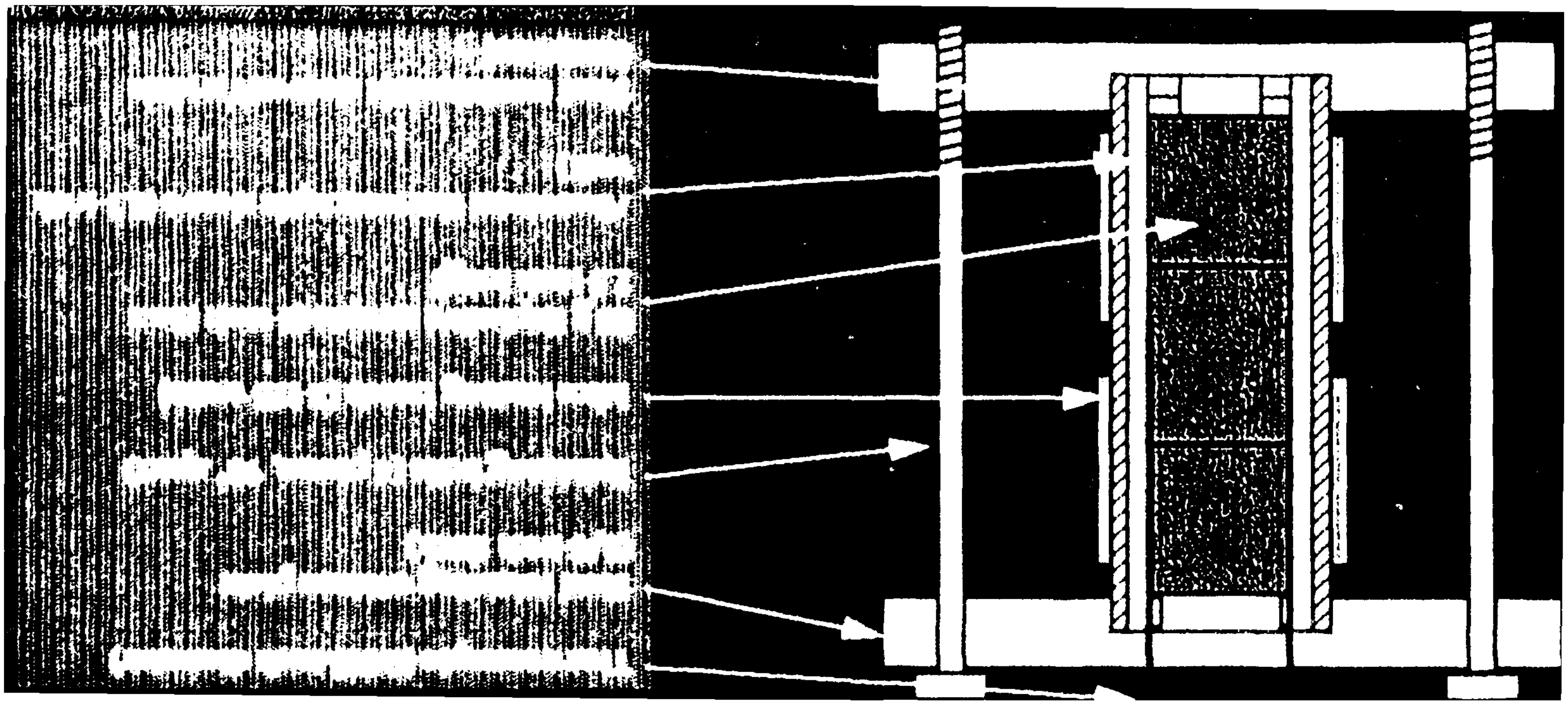




SAFETY AND VULNERABILITY TEST CONDITIONS

IMAD/HE

TEST / THREAT	DESCRIPTION
FAST COOKOFF	JP-5 FUEL FIRE, MINIMUM TEMPERATURE 1600°F
SLOW COOKOFF	SLOW HEATING, 6°F/HR
BULLET IMPACT	THREE 50 CAL AP BULLETS AT 2800 FT/S 50 ± 10 MS BETWEEN IMPACTS
SINGLE-FRAGMENT IMPACT	0.564-INCH DIAMETER STEEL CYLINDER FIRED FROM GUN
VARIABLE CONFINEMENT COOKOFF TEST	SLOW HEATING, 6°F/HR, WITH CONFINEMENT VARIED BETWEEN 1200 & 15300 PSI



VARIABLE CONFINEMENT COOKOFF TEST (VCCT)

TEST DESCRIPTION

AN EXPLOSIVE PELLET (1" DIAMETER X 2.5" LONG) IS PLACED IN AN ALUMINUM SLEEVE SURROUNDED BY A STEEL SLEEVE AND HEATED AT 6°F/HR UNTIL EXPLOSIVE SAMPLE REACTS

THE TEST IS REPEATED WITH A THICKER STEEL SLEEVE (BY 0.015") AND THE COOKOFF REACTION IS NOTED. THE EQUIVALENT PRESSURE OF CONFINEMENT THAT CAUSES THE EXPLOSIVE SAMPLE TO REACT MORE VIOLENTLY THAN A BURN IS USED AS A MEANS OF RANKING EXPLOSIVES IN TERMS OF SLOW COOKOFF BEHAVIOR

VARIABLE CONFINEMENT COOKOFF TEST

IMADHE

PRESSURE REQUIRED TO BURST STEEL CONFINEMENTS

CONFIGURATION	STEEL WALL THICKNESS (inch)	BURST PRESSURE (psi)
1	0.000*	1200
2	0.015	2350
3	0.030	5230
4	0.045	7725
5	0.060	10000
6	0.075	12700
7	0.090	15300**

* Aluminum sleeve without steel confinement sleeve
** Calculated

VCCT TYPICAL REACTION LEVELS

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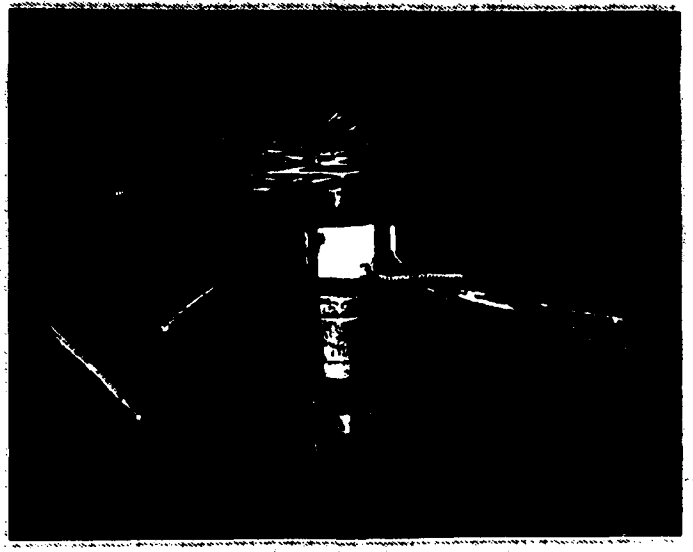
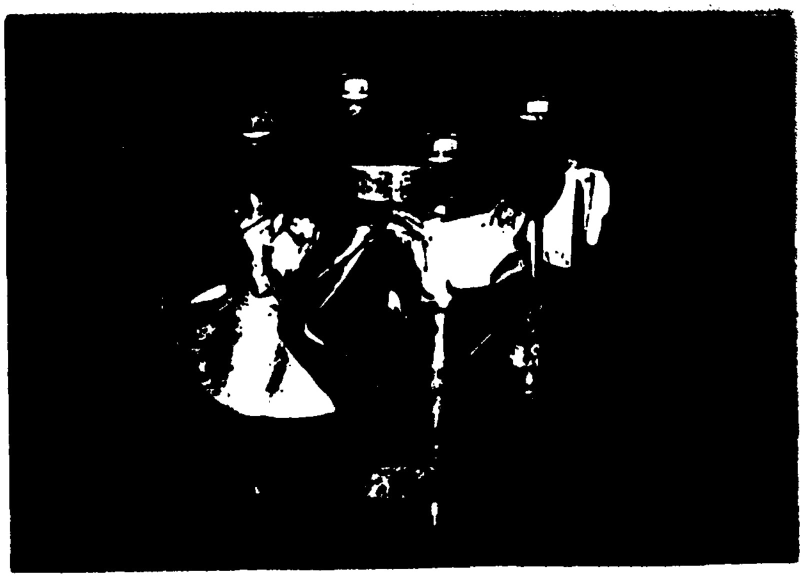
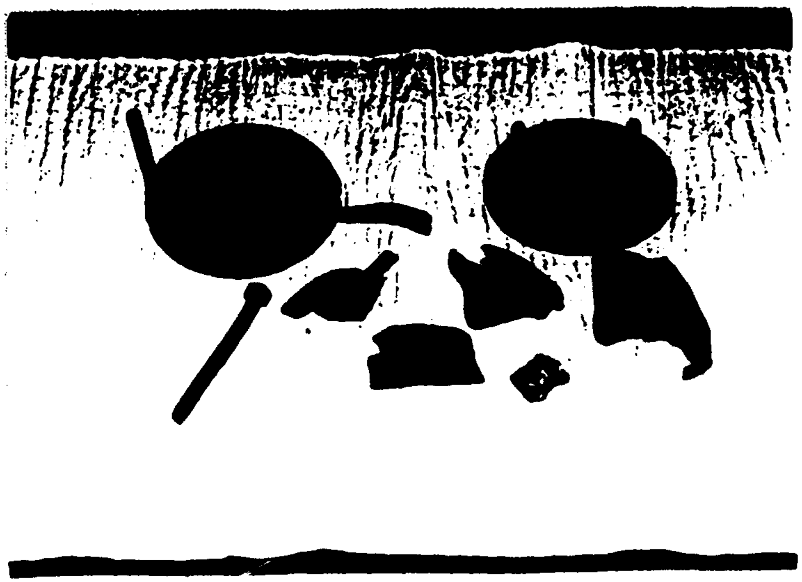


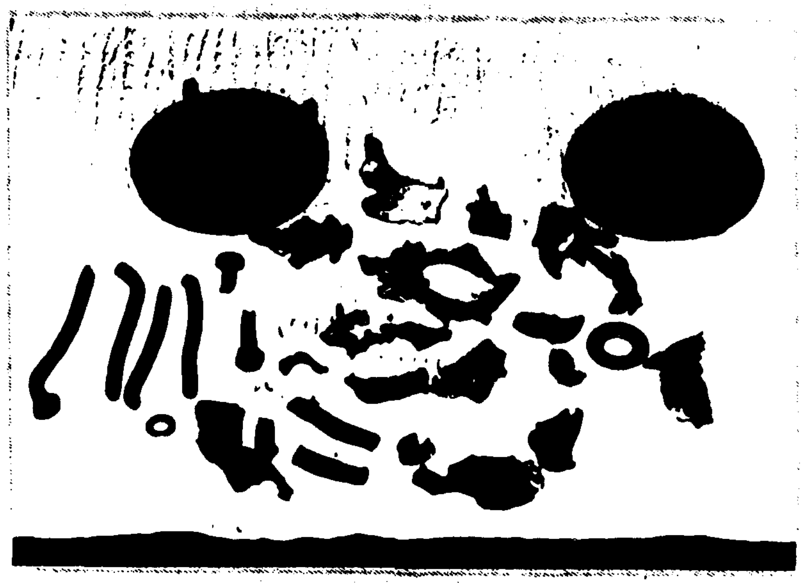
PRE-TEST



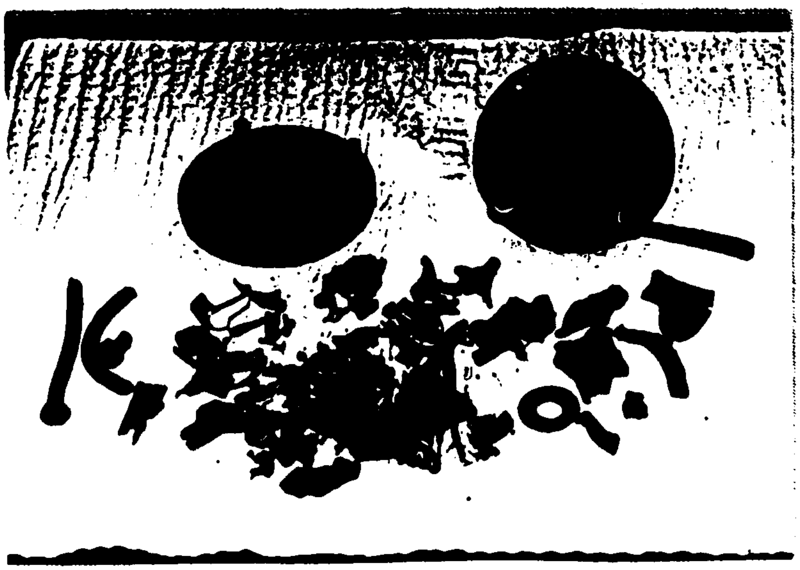


VCCT TYPICAL REACTION LEVELS

IMADHE



EXPLOSION



PARTIAL DETONATION

DETONATION

CANDIDATE METAL ACCELERATING EXPLOSIVES

IMAD/HE

FORMULATION	BINDER	WEIGHT PERCENT	EXPLOSIVE	WEIGHT PERCENT	DEVELOPER
LX-14(N)	Estane	4.5	HMX	95.5	LLNL[1]
PAX-2	NP/CAB	12 / 8	HMX	80	ARDEC[2]
PBXW-9 TYPE II(Q)	DOA/Hycar	6 / 2	HMX	92	NSWCDD
PBXW-11	DOA/Hycar	3 / 1	HMX	96	NSWCDD
PBXP-31	Silicone	4	HMX	96	MBB[3]
PBXC-129(Q)	LMA	11	HMX	89	NAWCWD[4]

[1]Lawrence Livermore National Laboratory
[2]Army Research and Development Engineering Command
[3]Messerschmitt Boelkow Blohm
[4]Naval Air Warfare Center Weapons Division, China Lake, California

VARIABLE CONFINEMENT COOKOFF TEST

IMADHE

EXPLOSIVE	PERCENT HMX	REACTION TEMP. °C	REACTION LEVEL AND PRESSURE
LX-14	95.5	189	P. DET. / 1.2 ksi
PAX-2	80	195	DEFL. / 7.7 ksi
PBXW-9	92	184	DEFL. / 15.3 ksi
PBXW-11	96	183	DEFL. / 7.7 ksi
PBXP-31	96	186	DEFL./ 10 ksi
PBXC-129	89	184	DEFL./ 15.3 ksi

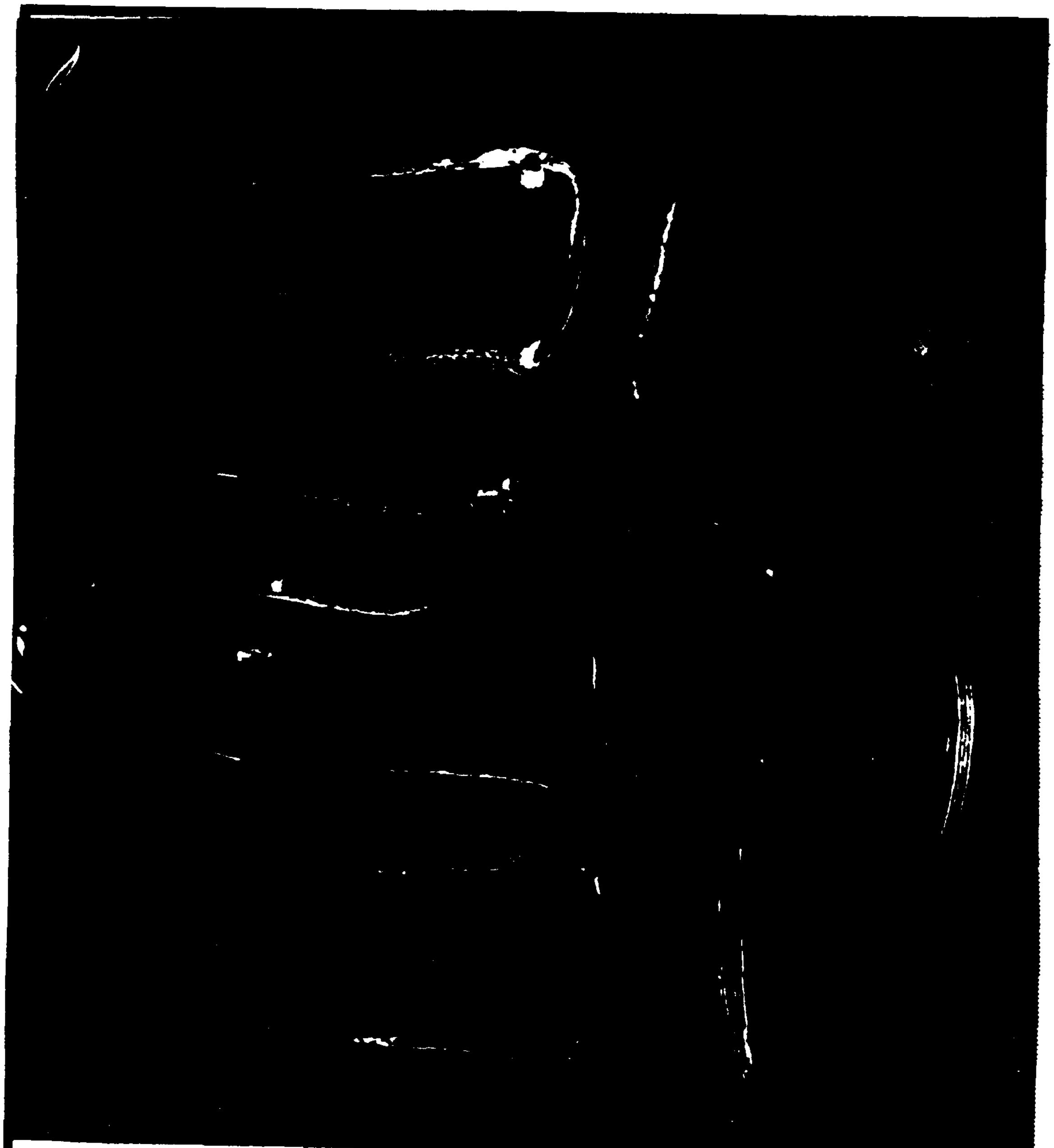
PENDING: OCTOL, PBXN-110

COMPARISON OF 3.2-IN. GSCTU SLOW COOKOFF TESTING AND VCCT TESTING

EXPLOSIVE	SCO	VCCT (PSI)
LX-14	DETONATION	1200
PAX-2	EXPLOSION	7725
PBXW-11	BURN	7725
PBXP-31	PARTIAL DETONATION	10000
PBXW-9	BURN	15300
PBXC-129	BURN	15300

SLOW COOK-OFF TEST PBXW-9
3.2-INCH GENERIC SHAPED CHARGE

IMADHE



SLOW COOK-OFF TEST PAX-2 IN
3.2 INCH GENERIC SHAPED
CHARGE HARDWARE

NAVAL SURFACE WARFARE CENTER
NSWC
A TRADITION OF EXCELLENCE

IMADHE


SLOW COOK-OFF TEST LX-14 IN
3.2 INCH GENERIC SHAPED
CHARGE HARDWARE
IMADHE
NAVAL SURFACE WARFARE CENTER
NSWC
A TRADITION OF EXCELLENCE

ORDNANCE HAZARD DURING AIRCRAFT RECOVERY OPERATIONS

Jack M. Pakulak, Jr.

Ordnance Systems Department
Naval Air Warfare Center
China Lake, CA 93555

ABSTRACT

This was a limited study on the thermal effects on specific aircraft-mounted ordnance. The initial effort was made with equipment using cartridge-actuated devices (CADs), since the CCU-44/B and Mk 124 CADs have been involved in accidental initiations on flight decks. The thermal behavior of the CADs and the thermal path that could have lead to their initiation (limited computer study) on the A-6 aircraft are presented in this paper.

INTRODUCTION

This study was made in response to the need for analysis of the effects of aircraft exhaust temperatures on ordnance during aircraft recovery operations. The study was limited to the thermal effects on specific aircraft-mounted ordnance,that used cartridge-actuated devices (CADs), since the CCU-44/B and Mk 124 CADs have been involved in accidental initiations on flight decks. In two or three known mishaps, an A-6 aircraft was taking the heat from an F/A-18 at the following estimated conditions:

Distance	Duration	Angle	Power
15 ft	5 minutes	45 degrees	>Idle
~50 ft	6-8 minutes	180 degrees	Idle
15 ft	15 minutes	180 degrees	>Idle

The level of heat was high enough to have blistered the paint on the bomb rack during the short period of time mentioned in the last mishap (see Appendix A). At an angle of 180 degrees, the worst mismatch of aircraft is a A-6 behind an F/A-18, F-14 or A-7 aircraft (Reference 1). This because of the forward wing location on an A-6 aircraft.

Another potential problem with the A-6 aircraft is the new replacement wings. The new wings are believed to have a composite material as part of the wing covering, such as used on the F/A-18 aircraft. These composite materials may have an upper temperature limit of 350-400°F and could be damaged by the exhaust heat from an aircraft engine.

This is part of the background information for this study and the thermal behavior of the CADs propellant and the limited computer study for predicting cookoff events.

EXPERIMENTAL

The experimental study covers a series laboratory-level testing. One part is for safety with regard to thermal effects; the other part is for data to predict the thermal behavior of the actual test item. The thermal behavior data on propellant material from the CADs were analyzed using the differential scanning calorimetry (DSC) technique with the variable heating method to determine the kinetic parameters. The other laboratory technique uses isothermal test conditions under the confined conditions of a Parr bomb test technique. The isothermal test produces a data plot of pressure versus time at a constant temperature. The test sample is weighed before and after testing in a Parr bomb that has a total volume of 45 cm^3.

The work described in this paper was sponsored by the Naval Sea Systems Command (C66I), Washington, D.C.

The DSC data from the two propellants showed a great deal of scattering for the heating rates and the peak temperatures. This was especially true with the CCU-44/B propellant. Both propellants are similarly preformed nitrate ester pellets, but the CCU-44/B propellant appeared to be slightly more thermally stable than the Mk 124 propellant.

Table 3 contains Parr bomb data for both propellants. The isothermal test temperatures for the CCU-44/B propellant were 212 and 230°F. For the Mk 124 propellant, the temperature was 230°F. The total duration for the tests was about 250 hours each. The Parr bomb data are used to verify the kinetic parameters calculated from the DSC data on these two propellants.

TABLE 3. Parr Bomb Data on CCU-44/B and Mk 124 Mod 0 Propellants.

Propellant	Temperature, °F	Duration, hours	Pressure, psi	Weight, grams	
				Start	Finish
CCU-44/B	82	0	0	0.7675	0.6334
	212	2	3		
	"	20	5		
	"	110	10		
	"	224	22		
(Power off)	75	234	11		
CCU-44/B	230	10	24	0.9294	0.3758
	"	100	52		
	"	228	107		
(Power off)	82	254	77		
Mk 124	230	12	24	0.9392	0.3892
(Lost pressure)		60	33 (lost pressure)		
(Power off)	230	120 (est.)	100 (est.)		
	82	254	~30		

The Mk 124 propellant Parr bomb sample lost pressure after about 60 hours of heating at 230°F. At this time we believe that the weight loss and pressure rise are related. The weight loss fraction was 0.18 at 212°F and 0.59 at 230°F for the CCU-44/B propellant, and 0.60 at 230°F for the Mk 124 propellant. These weight loss fractions were assumed the same as the fraction reacted, F*. The fraction reacted, F*, based on Equation 2, is used to calculate the specific rate constant, k, at a given temperature over a given time, t.

$$-\ln(1 - F^*) = kt \tag{2}$$

The k values for CCU-44/B and Mk 124 propellants at 212 and 230°F were determined from the weight loss fractions and are given in Table 4.

TABLE 4. Determination and Comparison of Specific Rate Constant, k, Values.

Propellant	Temperature, °F	Parr bomb k values	DSC predicted k values
CCU-44/B	212	2.7×10^{-7} 1/s	1.0×10^{-7} 1/s
	230	1.1×10^{-6} 1/s	5.3×10^{-7} 1/s
Mk 124	230	1.2×10^{-6} 1/s	1.1×10^{-6} 1/s

A data plot of the CCU-44/B Parr bomb data, using Equations 1 and 2, yielded a value of 41.8 kcal/mole for E and 17.88 1/s for log Z. These values are much closer to the DSC kinetic parameters developed for the Mk 124 propellant than to the CCU-44/B propellant.

Appendix A
HAZARDOUS MATERIAL REPORT

The data contained in this appendix were obtained from a message to the Naval Ordnance Station, Indian Head, Md., from TACERLRON 141.

A. OPNAVINST 4790.2E
B. TACERlron 141 Class A GM 01-90

1. VAQ-141/53807
2. NAVORDSTA INDIAN HEAD MD
3. R53887-90-0025
4. 0176/USS Theodore Roosevelt &CVN-71, at sea
5. NSN 1377-00-193-8832
6. Mk 124 Mod 0 impulse cartridge
7. Marvin Engineering Co. Inc., 32067, UNK
8. 30083
9. Lot No. WE187L004-001
10. UNK
11. New
12. UNK
13. 5 days
14. N/A
15. N/A
16. A. AERO-7A-5
    B. EA-6B
17. Four cartridges at DLR.2.61 each,N/A
18. N/A
19. UNK
20. None
21. Holding exhibit 30 days for investigation on board CVN-71. CFA response not required.
22. A. EA-6B aircraft &BUNO 16527, side NR 621 was parked on the starboard bow. One round of CVN-71 facing aft with its port wing partially over the catwalk. An F/A-18 was park4ed directly aft of 621 with wing overlap. During first event engine starts, it was noticed that the F/A-18 exhaust was blowing on wing station one of 621. The air boss and flight deck control were notified of the situation and flight deck control sent an aircraft handler over to taxi 621 out of the area. As the tie down chains were removed

M363
CARTRIDGE, IMPULSE, MARK 124 MOD 0

NAVAIR P/N 2838195 **NSN 1377-00-193-8832**

(FORMERLY — CARTRIDGE, IMPULSE EX 124 MOD 0)

NOTE

The M363 Impulse Cartridge is being replaced by the MD65 Impulse Cartridge on a one-for-one basis, in some applicaitons. For specific cartridge utilization, refer to the appropriate loading manual.

1-1. FUNCTION.

1-2. Impulse Cartridge Mark 124 Mod 0 (fig. M363-1) is used as the power source in stores release/ejection mechanisms on aircraft.

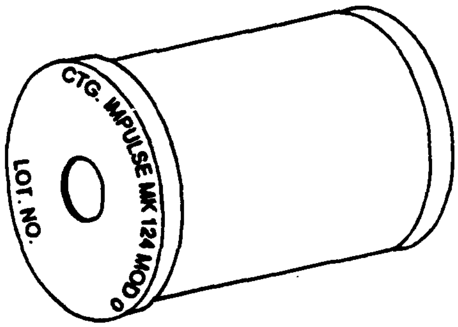


Figure M363-1. Impulse Cartridge
Mark 124 Mod 0

2-1. DESCRIPTION AND LOCATION.

2-2. The cartridge is electrically initiated and consists of a case, an ignition element assembly, and propellant. The cartridge case is crimped over a consumable closure assembly (fig. M363-2).

2-3. Dimensions of the cartridge are: diameter, 1.056-inches; length, 1.650-inches.

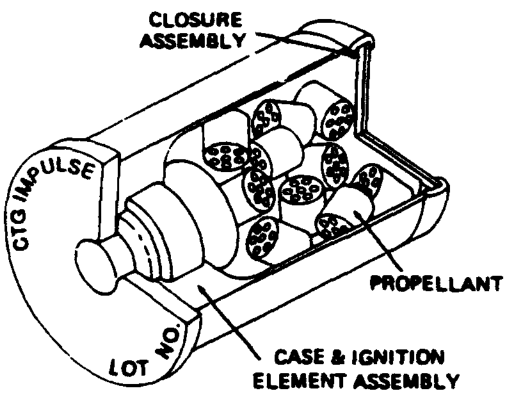


Figure M363-2. Impulse Cartridge
Mark 124 Mod 0, Sectioned

3-1. OPERATION.

3-2. When the cartridge is fired, the resulting gas pressure operates the store release/ejector mechanism.

3-3. Operating temperature range of the cartridge is from -65°F to +200°F. The minimum firing current is 5 amperes.

4-1. IDENTIFICATION AND HANDLING.

4-2. The following data are stamped on the base of each cartridge case: CTG, IMPULSE, MK 124 MOD 0, and the cartridge lot number.

4-3. PACKAGING AND STORAGE. The Mark 124 Mod 0 impulse cartridge is packaged 40 to a hermetically sealed metal container (fig. M363-3). Cartridges are packed tightly with adequate separation, support, and cushioning to prevent damage in storage and normal handling.

accordance with the general safety precautions given in the Safety Summary.

WARNING

BEFORE INSTALLING THE CARTRIDGE IN THE BREECH, BE SURE THAT ALL CIRCUITS OF THE ACTUATING SYSTEM ARE OPEN.

THIS CARTRIDGE SHALL NOT BE RESISTANCE-CHECKED EITHER PRIOR TO OR AFTER INSTALLATION IN THE DEVICE ON INTENDED APPLICATION.

THIS CARTRIDGE SHALL NOT REPLACE THE IMPULSE CARTRIDGE MK 1 MOD 3 WHERE ONLY ONE MK 1 MOD 3 IS USED.

CAUTION

Grease or oil shall not be applied to the cartridge.

CAUTION

Results indicate that if cartridges are installed in certain types of devices, then removed and reinstalled in different types of devices, electrical contact will be marginally possible. Therefore, cartridges should be reinstalled only in the original installation.

6-3. HERO CLASSIFICATION. SAFE in all tested applications. UNSAFE, untested in others. Refer to NAVAIR OP 3565.

6-4. EXPLOSIVE WEIGHT. The cartridge explosive weight is 0.018394 pound for each unit. Total explosive weight per package can be obtained by multiplying number of units times unit explosive weight.

6-5. EXPLOSIVE CLASS. The explosive classes of this item are:

NATO (UN)	Class 1 Division 4
DOD	Class 1
DOT	Class C

MD66
CARTRIDGE, IMPULSE, CCU-44/B

NAVAIR P/N 5184850 **NSN 1377-01-063-3161**
1377-01-063-3164
1377-01-063-3165

NOTE

Impulse Cartridge CCU-44/B is designed as a replacement for Impulse Cartridges M364 Mark 125 Mod 0 and M190 Mark 2 Mod 1. For specific CARTRIDGE UTILIZATION, refer to the appropriate loading manual.

1-1. FUNCTION.

1-2. Impulse Cartridge CCU-44/B (fig. MD66-1) is used as a power source for the ejection of stores from aircraft missile launchers and bomb racks.

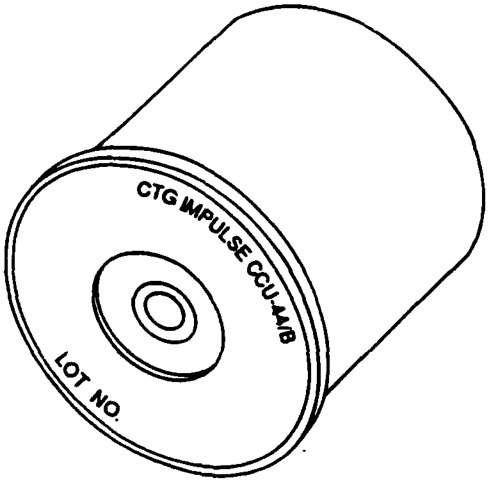


Figure MD66-1. Impulse Cartridge CCU-44/B

2-1. DESCRIPTION AND LOCATION.

2-2. The CCU-44/B cartridge is an electrically initiated cartridge installed in the firing chamber of the ejection mechanism of a missile launcher or bomb rack. The cartridge consists of a case, electrode, ignition element, main charge, and cap closure assembly (fig. MD66-2).

2-3. Dimensions of the cartridge are: length, 1.100-inches; diameter, 1.080-inches.

3-1. OPERATION.

3-2. Upon receipt of an electrical signal, the ignition element is fired and the resulting gas pressure ignites the main charge. When sufficient pressure is developed, the cup closure assembly ruptures and the released gas pressure actuates the release/ejector mechanism.

3-3. The operating temperature range of the cartridge is from -65°F to +200F. Recommended firing current is 10 amperes.

4-1. IDENTIFICATION AND HANDLING.

4-2. Stamped on each cartridge case is nomenclature (CCU-44/B) and the cartridge lot number.

4-3. PACKAGING AND STORAGE. Impulse Cartridge CCU-44/B is packaged in three quantities. When ordered under NSN 1377-01-063-3161, the cartridge is packaged 60 to a hermetically sealed container; with NSN 1377-01-063-3164 it is packaged 80 to the container; and with NSN 1377-01-063-3165, it is packaged 10 to the container. The cartridges are packaged with adequate separation, support, and cushioning to prevent damage during storage and normal handling.

4-4. Identification data on the hermetically sealed container consists of NSN and DODIC, cartridge nomenclature, cartridge P/N, quantity, and cartridge lot number.

6-1. SAFETY.

6-2. SAFETY PRECAUTIONS. Impulse Cartridge CCU-44/B shall be handled, shipped, and stored as Class C ammunition in accordance with the general safety precautions given in the Safety Summary.

WARNING

BEFORE INSTALLING THE CARTRIDGE IN THE FIRING BREECH, ENSURE THAT ALL CIRCUITS OF THE ACTUATING SYSTEM ARE OPEN.

THE CARTRIDGE SHALL NOT BE RESISTANCE-CHECKED EITHER PRIOR TO OR AFTER INSTALLATION IN THE DEVICE OF INTENDED APPLICATION.

CAUTION

Grease or oil shall not be applied to this cartridge.

6-3. HERO CLASSIFICATION. SAFE in all tested applications, UNSAFE in some untested applications. Refer to NAVAIR OP 3565.

6-4. EXPLOSIVE WEIGHT. Explosive weight of the CCU-44/B cartridge is 0.009923 pound for each unit. Total explosive weight per package can be obtained by multiplying number of units times unit explosive weight.

6-5. EXPLOSIVE CLASS. The explosive classes applicable to the CCU-44/B cartridge are:

NATO (UN)	Class 1 Division 4
DOD	Class 1
DOT	Class C

Appendix C
COMPUTER STUDY OF CAD COOKOFF

DEPARTMENT OF THE NAVY
NAVAL WEAPONS CENTER
CHINA LAKE, CALIFORNIA 93555-6001

IN REPLY REFER TO
8800
3593/050
10 Oct 91

MEMORANDUM

From: G. W. Thielman, Thermal Analysis Branch (Code 3593)
To: J. M. Pakulak, Thermal & Process Evaluation Branch (Code 3212)
Via: Head, Thermal Analysis Branch (Code 3593)

Subj: CAD COOKOFF EVALUATION DUE TO AIRCRAFT TURBINE ENGINE IMPINGEMENT

Ref: (a) NAVAIR 11-5-603, Technical Manual: Organizational, Intermediate, and Depot Maintenance Instruction Manual with Illustrated Parts Breakdown Improved Multiple Ejector Rack (IMER) BRU-41/A and Improved Triple Ejector Rack (ITER) BRU-42/A, 1 Apr 88
(b) NWC TP 6887, Thermal Hazards to Ordnance and Aircraft Aboard an Aircraft Carrier Flight Deck, G. A. Vernon, V. V. Kodas, W. D. Williams, Sep 88
(c) Chapman, A.P., *Heat Transfer*, Macmillan, 1974, eqn. 8.44, 8.45, pg. 357

1. Incidents of uncommanded ordnance release have been reported on aircraft carrier decks. This has been attributed to initiation of a gas-generating Cartridge Activated Device (CAD) on a Triple Ejector Rack (TER)-7 as a consequence of engine exhaust heating. The minimum distance between ordnance aft of a turbine engine exhaust nozzle is 10 feet. The Thermal Analysis Branch (Code 3593) was tasked to evaluate the propensity of the CAD to cookoff due to this heat load.

2. A two-dimensional axisymmetric geometric PATRAN and corresponding thermal SINDA model was created using SINGEN. The model included a titanium breech, electrical connector and CAD. Physical dimensions were measured from hardware obtained for this purpose. Information on breech arrangement within and physical dimensions of the TER was determined using a manual for the comparable next generation rack in reference (a). The TER was treated as a lumped mass corresponding to appropriate mass and surface area. Two CAD designs were modeled for comparison within the breech geometry. The two model configurations are illustrated in Figure 1.

3. Chemical reaction and internal energy generation of the energetic materials is modeled as a function of temperature change, with the following Arrhenius relation:

$$\frac{dT}{dt} = \frac{QZ}{c}\exp(-E/RT)$$

where dT/dt is temperature change with time, Q is heat of decomposition, Z is collision frequency, c is heat capacity, E is activation energy and R is the universal gas constant which is 1.987 cal/gm-mole °K or Btu/lb-mole °R.

7. Due to the use of two independent variables: exhaust velocity and temperature, the results are plotted in both two and three dimensional form. Graphs showing the boundary condition relation between velocity and temperature, along with initiation time as a function of these two variables is shown in two-dimensional form in Figure 2. A more isometric version to provide an image of interrelationship between the independent and dependent variables is illustrated in Figure 3.

8. Results indicate that Mark 124 pellets are more sensitive than CCU-44/B pellets for this configuration. The model predicts that the former will cookoff in 22 minutes at idle power, though this is subject to uncertainty. The worst-case assumptions with stagnation convection and exhaust temperature radiation applied axisymmetrically represent extreme physical conditions. A three-dimensional detailed study is recommended. Nonetheless, the sensitivity of Mark 124 suggests additional measures to protect the TER CAD from engine exhaust might be prudent.

G. W. THIELMAN

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3593 (file)

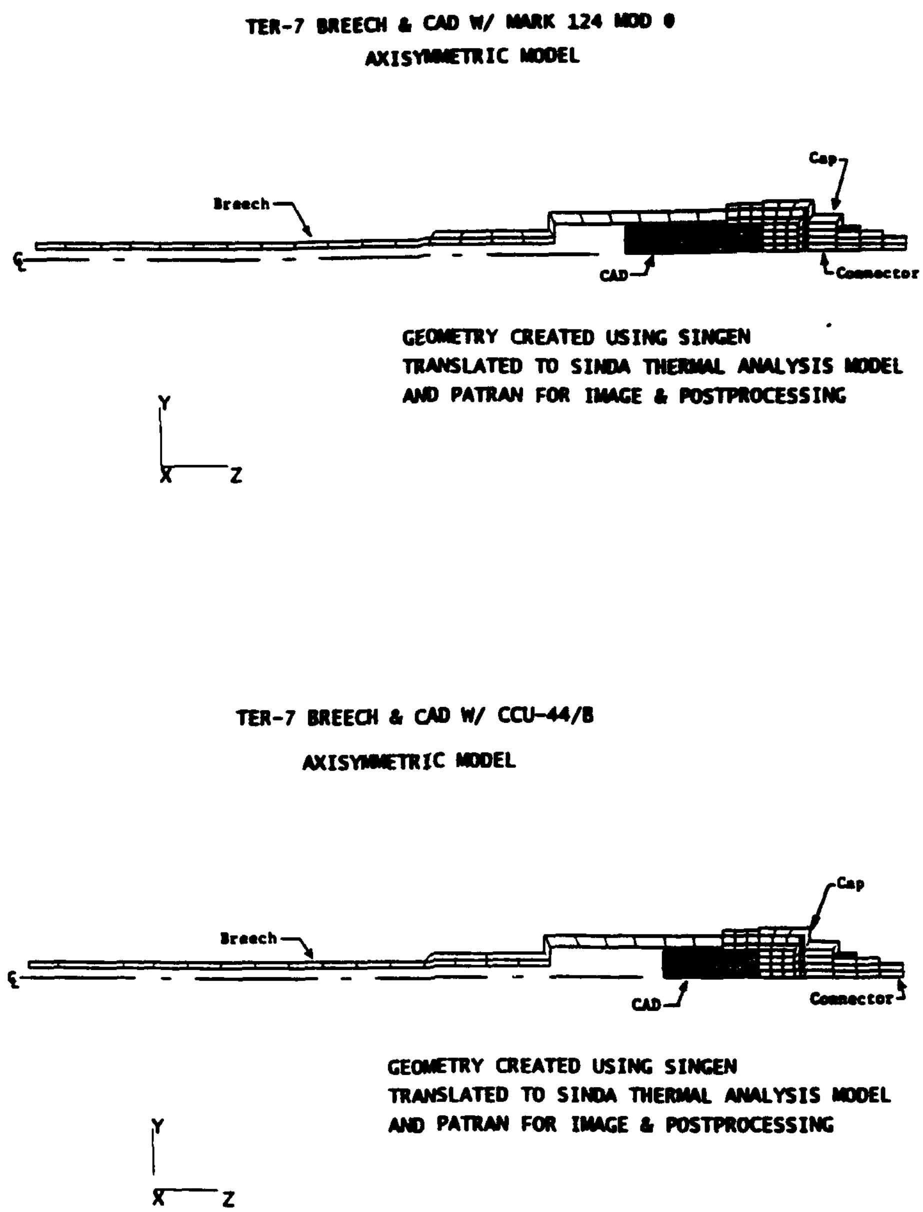


FIGURE 1. PATRAN Geometry Models of the TER-7 Breech and CAD

TER–7 CAD INITIATION

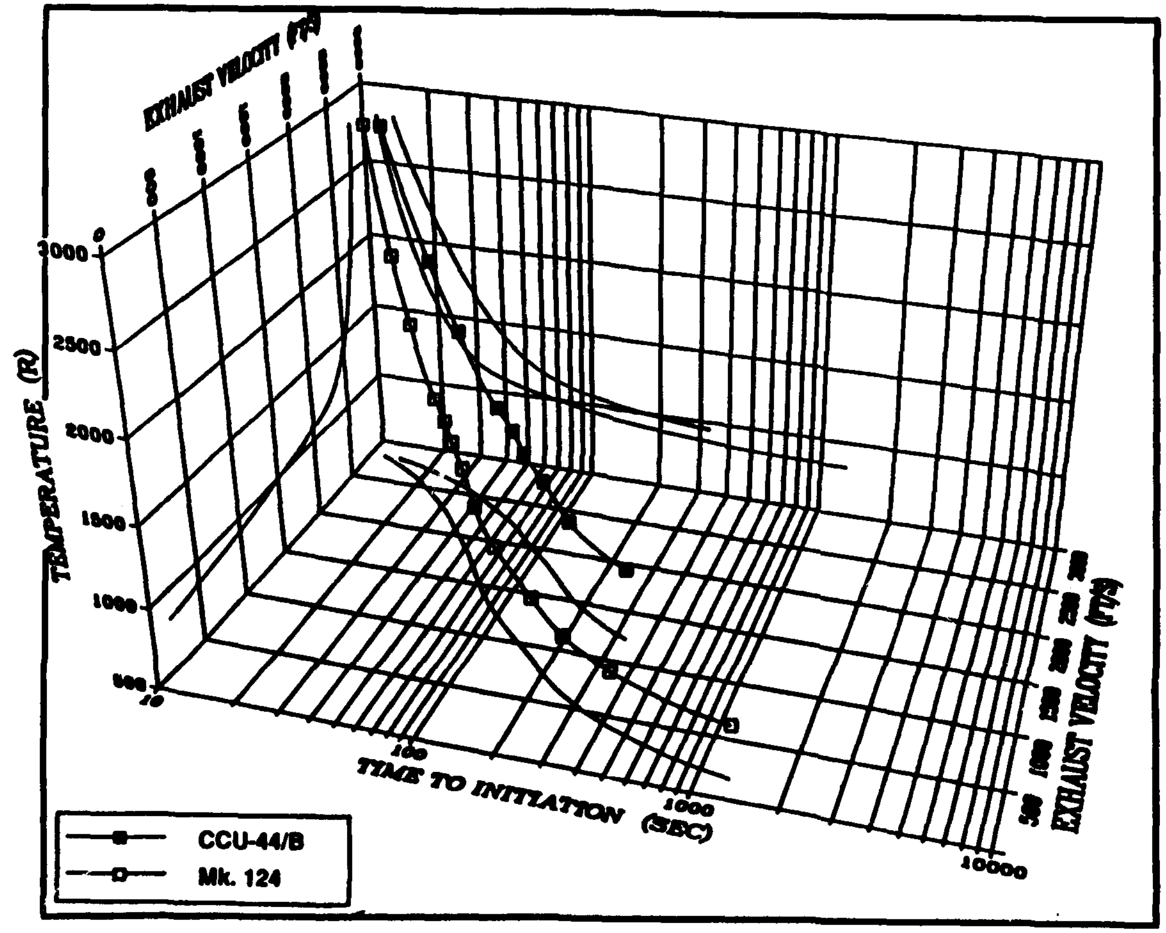


FIGURE 3. TER-7 CAD Cookoff Initiation Profiles in 3-D Plot

Fifth Tri-Service Symposium on Explosive Testing

Department of Defense Explosives Safety Board

NAWC
Weapons Division
NAVAL AIR WARFARE CENTER

Ordnance Hazard During Aircraft Recovery Operations

by
Jack M. Pakulak, Jr.
Naval Air Warfare Center, China Lake, CA 93555
14-15 April 1993

Ordnance Hazard During Aircraft Recovery Operations

- A limited study on the thermal effects of specific ordnance
  - Aircraft mounted Ordnance
    - Equipment using cartridge-actuated devices (CADs)
    - Involved CADs were the CCU-44/B and Mk-124 mod 0

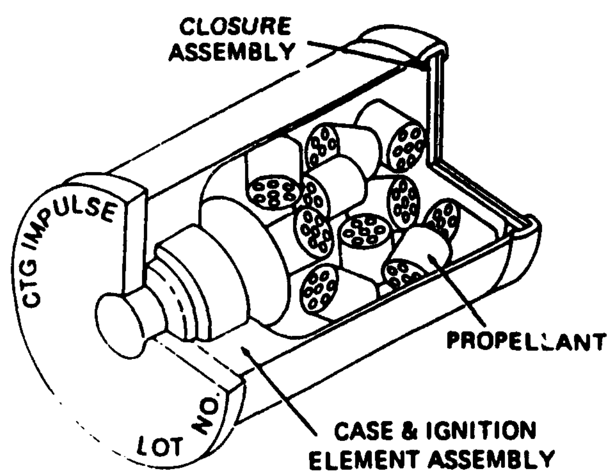


Figure M363-2. Impulse Cartridge
Mark 124 Mod 0, Sectioned

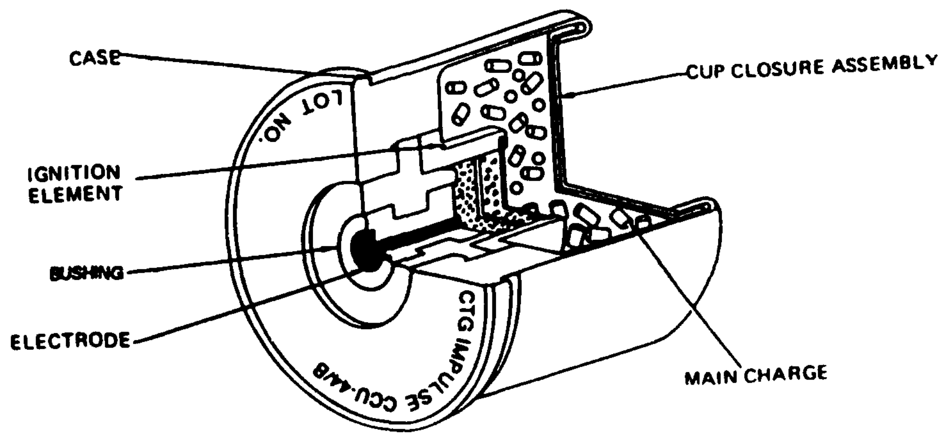


Figure MD66-2. Impulse Cartridge CCU-44/B, Sectioned

Ordnance Hazard During Aircraft Recovery Operations

- Aircraft mounted Ordnance (cont.)
  - Accidental initiations on flight decks

Distance	Duration	Angle	Power
15 feet	5 minutes	45°	>Idle
~50	6 - 8	180°	Idle
15	15	180°	>Idle

Propellant	Description	Pellet size (L·Dia·Wt)
CCU-44/B	#4 Lot AMN86G007-039	0.17" x 0.14" x 63 mg
Mk-124-0	#5 Lot 2SP009-78 #1 Lot 6WE10780	0.24" x 0.26" x 306 mg

- The operating temperature is from -65°F to +200°F

Ordnance Hazard During Aircraft Recovery Operations

- **Thermal stability of propellants**

TABLE 1. CCU-44/B CAD Propellant DSC Data.

Heating rate, K/min	Peak temperature, K	Sample weight, mg	Exothermic heat (Q), cal/g-K
0.63	446.7	1.01	389
1.0	443.8	6.42	508
1.25	442.8	5.85	486
2.0	452.5	1.51	460
2.5	451.2	3.30	Blew[a]
5.0	455.7	1.90	Blew[a]
10.0	453.0	1.60	Blew[a]
20.0	452.4	1.40	Blew[a]
40.0	466.0	0.80	...
			460 (av.)

[a] The sample blew before the DSC peak temperature was reached.

- **Thermal stability of propellants**

TABLE 2. Mk 124 Mod 0 CAD Propellant DSC Data.

Heating rate, K/min	Peak temperature, K	Sample weight, mg	Exothermic heat (Q), cal/g-K
0.63	445.2	1.77	...
1.0	447.8	2.15	448
2.5	458.1	2.30	454
5.0	465.3	0.70	418
10.0	456.9	1.10	Blew[a]
20.0	451.8	2.00	Blew[a]
40.0	450.2	2.60	Blew[a]
			440 (av.)

[a] The sample blew before the DSC peak temperature was reached.

Ordnance Hazard During Aircraft Recovery Operations

- **Thermal stability of propellants**

TABLE 3. Parr Bomb Data on CCU-44/B and Mk 124 Mod 0 Propellants.

Propellant	Temperature, °F	Duration, hours	Pressure, psi	Weight, grams	
				Start	Finish
CCU-44/B	82	0	0	0.7675	0.6334
	212	2	3		
	"	20	5		
	"	110	10		
	"	224	22		
(Power off)	75	234	11		
CCU-44/B	230	10	24	0.9294	0.3758
	"	100	52		
	"	228	107		
(Power off)	82	254	77		
Mk 124	230	12	24	0.9392	0.3892
(Lost pressure)		60	33 (lost pressure)		
(Power off)	230	120 (est.)	100 (est.)		
	82	254	~30		

Ordnance Hazard During Aircraft Recovery Operations

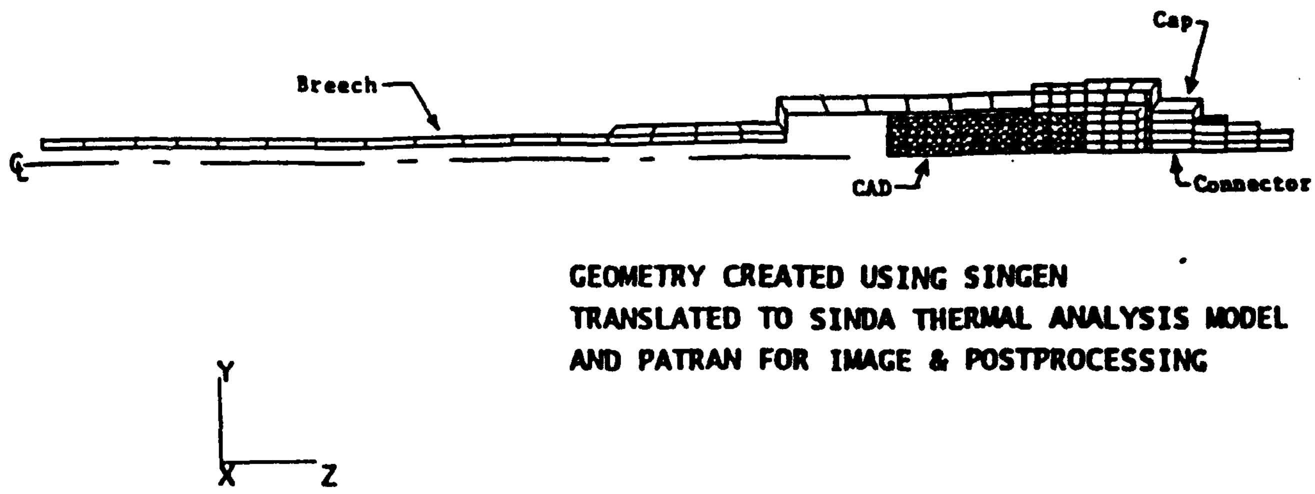
- **Thermal stability of propellants**

TABLE 4. Determination and Comparison of Specific Rate Constant, k, Values.

Propellant	Temperature, °F	Parr bomb k values	DSC predicted k values
CCU-44/B	212	2.7×10^{-7} 1/s	1.0×10^{-7} 1/s
	230	1.1×10^{-6} 1/s	5.3×10^{-7} 1/s
Mk 124	230	1.2×10^{-6} 1/s	1.1×10^{-6} 1/s

Ordnance Hazard During Aircraft Recovery Operations

- Computer Studies on Propellants
  - A two-dimensional axisymmetric geometric PATRAN and corresponding thermal SINDA model was created using SINGEN
  - Model included: titanium breech, electrical connector & CAD within the Triple Ejector Rack (TER)
  - Minimum distance of 10 feet between ordnance aft of tu:bine engine exhaust nozzle
  - TER-7 Breeh & CAD w/Mk-124-0 Axisymmetric Model.

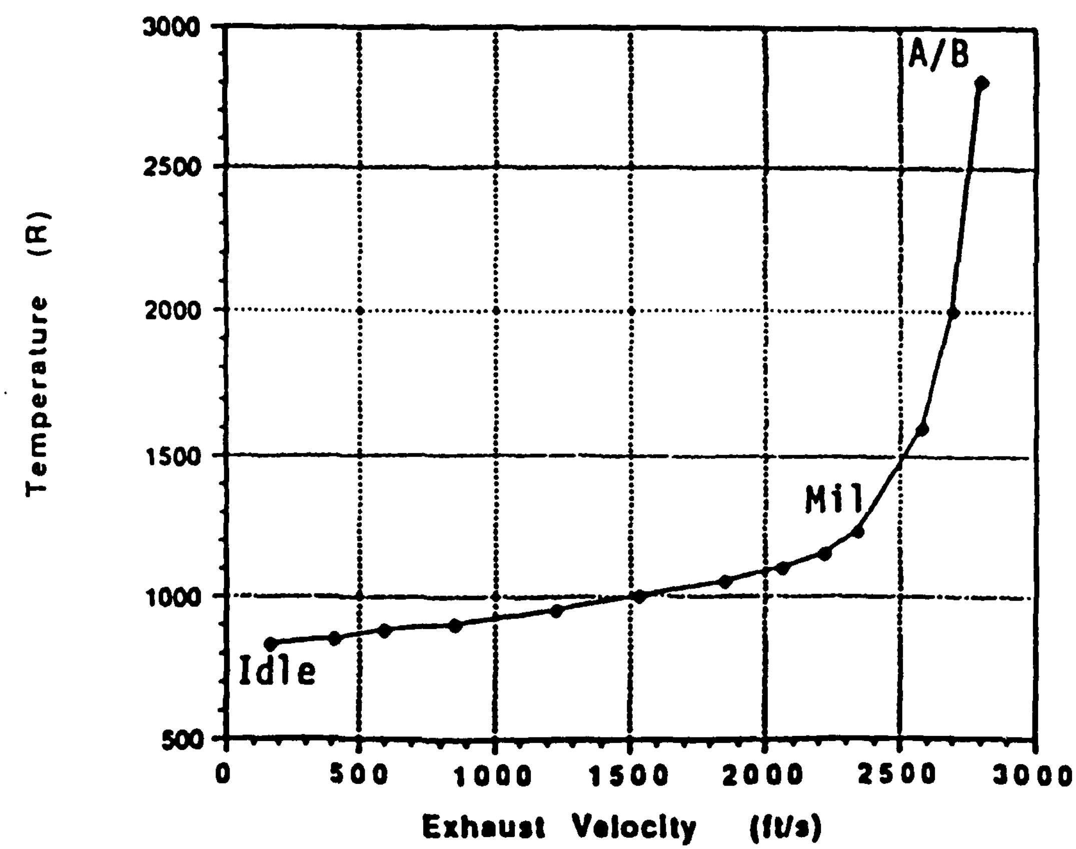


GEOMETRY CREATED USING SINGEN
TRANSLATED TO SINDA THERMAL ANALYSIS MODEL
AND PATRAN FOR IMAGE & POSTPROCESSING

Ordnance Hazard During Aircraft Recovery Operations

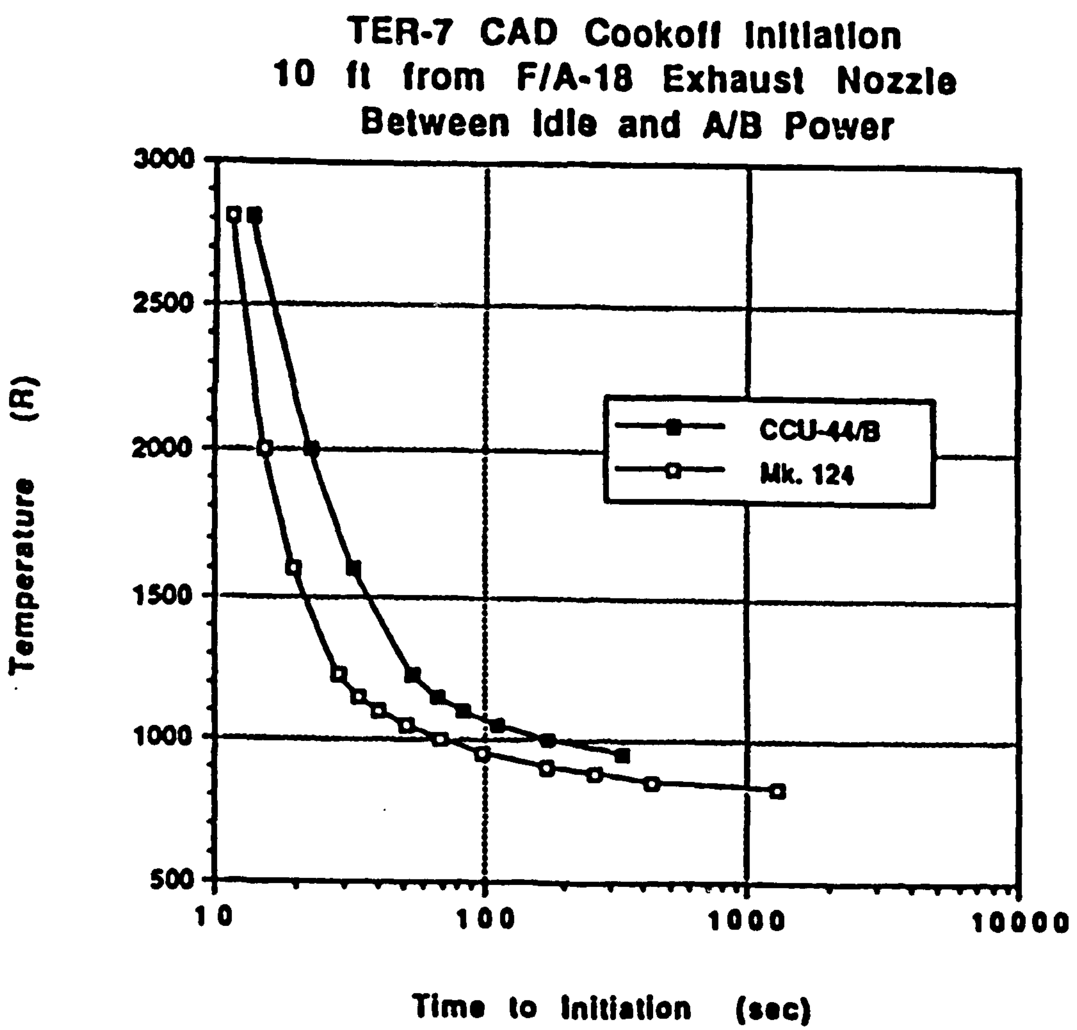
- Computer Studies on Propellants

TER-7 CAD Cookoff Condition Profile
10 ft from F/A-18 Exhaust Nozzle
Between Idle and A/B Power



Ordnance Hazard During Aircraft Recovery Operations

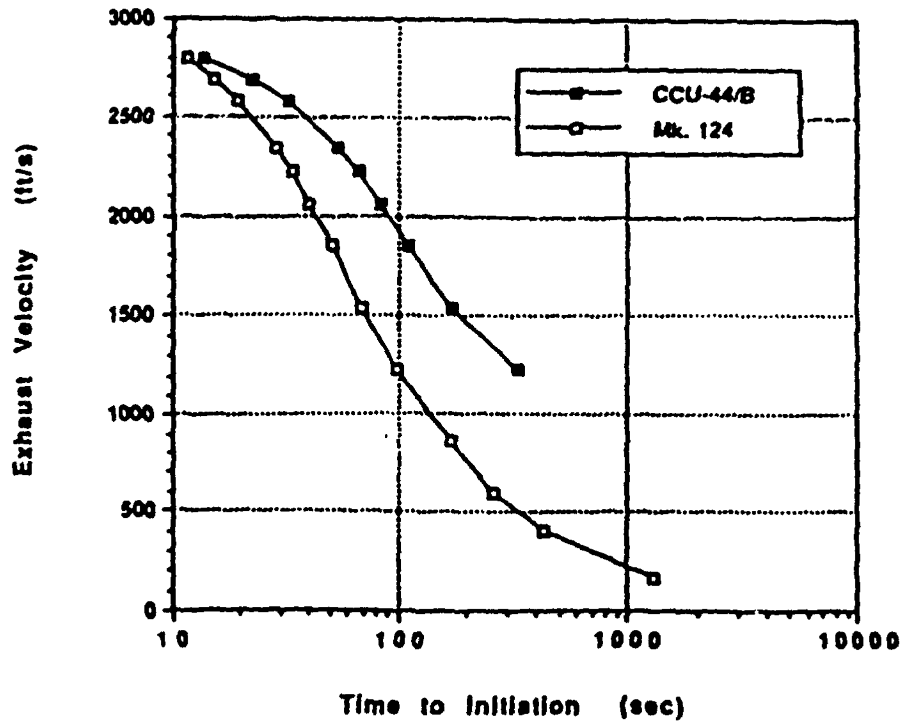
- Computer Studies on Propellants



Ordnance Hazard During Aircraft Recovery Operations

- **Computer Studies on Propellants**

TER-7 CAD Cookoff Initiation
10 ft from F/A-18 Exhaust Nozzle
Between Idle and A/B Power



- **Computer Studies on Propellants**

TER–7 CAD INITIATION

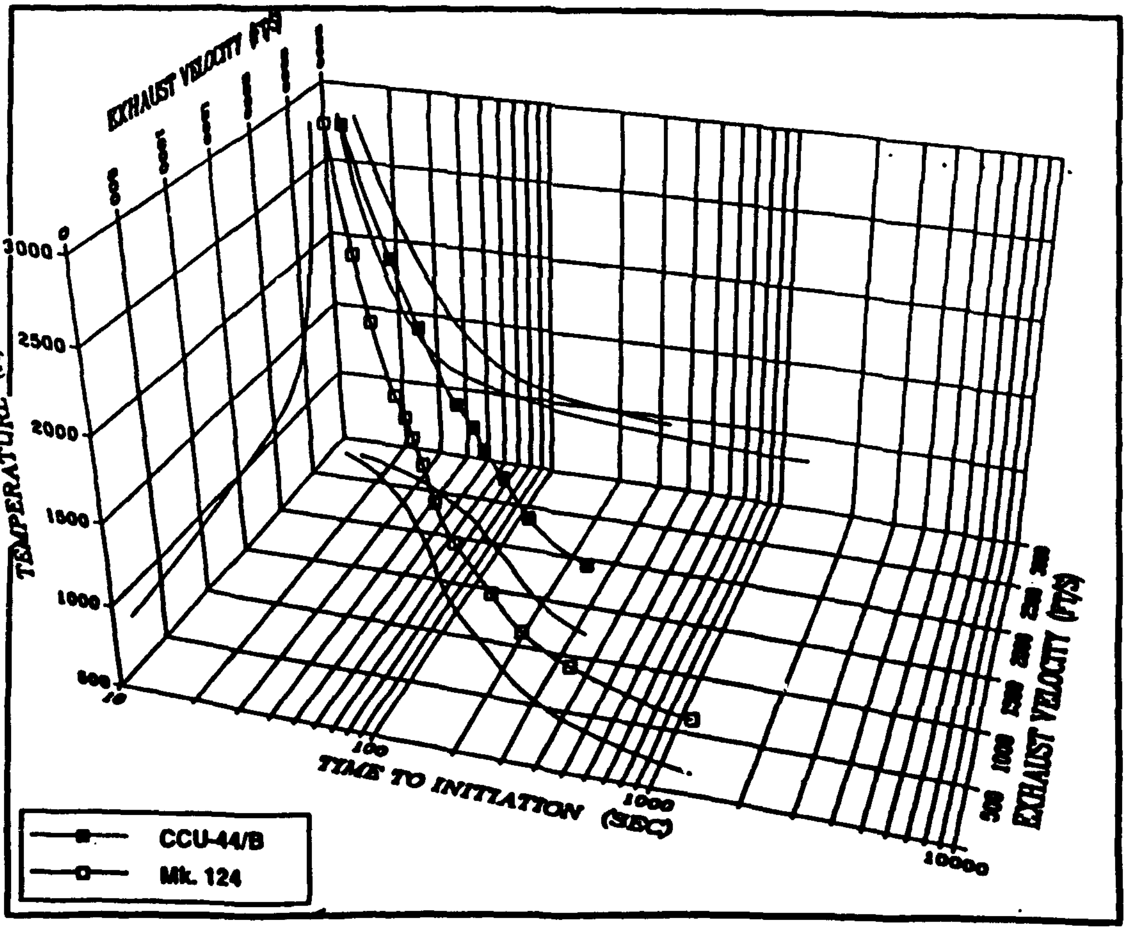


FIGURE 3. TER-7 CAD Cookoff Initiation Profiles in 3-D Plot

Ordnance Hazard During Aircraft Recovery Operations

- SUMMARY
  - CADs do cook off
  - Blistered Paint
  - Laboratory & Computer Study
  - Study suggest higher Exhaust Temp.

EXECUTIVE SUMMARY

SAFELOAD PROGRAM OVERVIEW

ROBERT A. ROSSI
OFFICE OF THE PROJECT MANAGER FOR AMMUNITION LOGISTICS
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The Safeload Program (formerly Quickload Program) was originated in 1984 and provides materiel and information technology solutions to reduce hazards and increase survivability throughout the ammunition logistic system. The program's goal is to eliminate explosives safety waivers and violations and to minimize the risks of residual explosive hazards. The program addresses ammunition storage problems identified by Army Major Commands, the Department of Defense Explosives Safety Board (DDESB), and the U.S. Army Technical Center for Explosives Safety (USATCES).

Originally, the Safeload Program was concerned with providing interim solutions for the unsafe storage of basic load ammunition in ammunition holding areas in Korea. Technical Data Packages were developed, tested, DDESB approved, and distributed to the field for download racks for 105mm and 120mm tank ammunition, 4.2" mortar, TOW missile, and sand grid and Agan Steel Panel (ASP) barriers for the storage of uploaded artillery ammunition trucks.

Since that time, the Safeload Program has grown to address explosives safety concerns throughout the various theaters. PM-AMMOLOG has continued to manage the development of engineering solutions to problems received from the field and has become the focal point in the Army for technology solutions to explosives safety storage and quantity distance problems.

The program is currently executed by explosives safety experts in the U.S. Army, Navy, Air Force, and Department of Energy. Most projects have joint service cooperation, participation, and funding. We welcome new opportunities to participate with other services to address common explosives safety concerns.

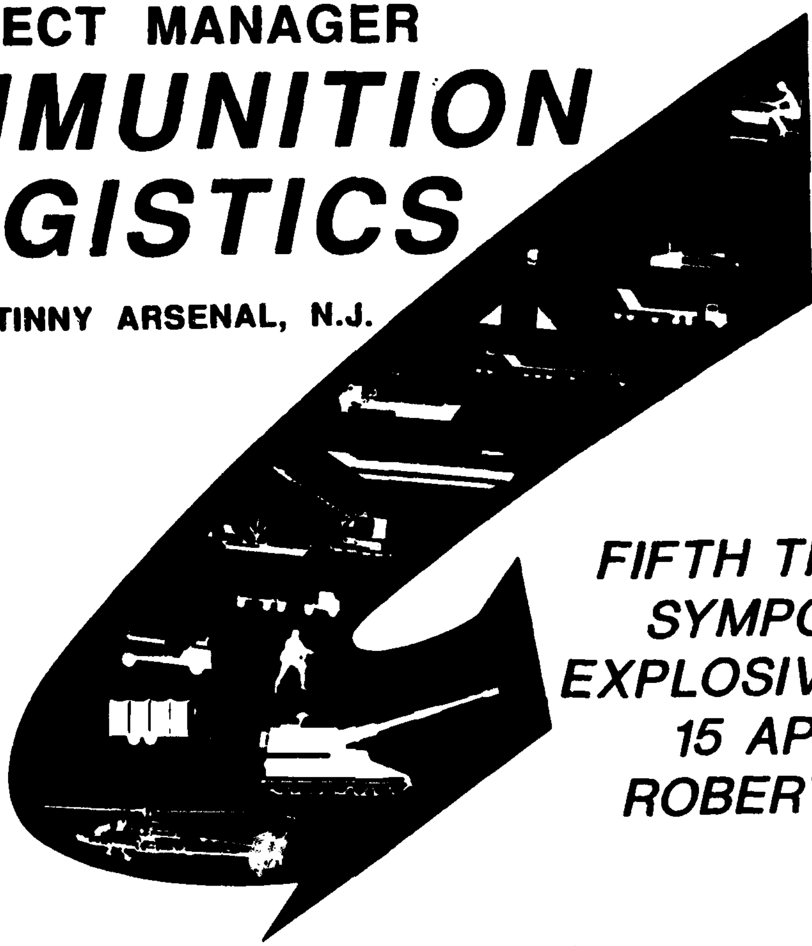
U.S. ARMY SAFELOAD EXPLOSIVES SAFETY PROGRAM

PROJECT MANAGER AMMUNITION LOGISTICS

PROJECT MANAGER

AMMUNITION LOGISTICS

PICATINNY ARSENAL, N.J.



FIFTH TRI-SERVICE SYMPOSIUM ON EXPLOSIVES TESTING

15 APRIL 1993

ROBERT A. ROSSI

OUTLINE

- *PURPOSE*
- *BACKGROUND*
- *EXPLOSIVES TESTING PROJECTS*
- *PROJECTS WHICH USE COMPUTER CODES BASED ON EXPLOSIVES TESTING*
- *WRAP-UP*
- *SUMMARY*

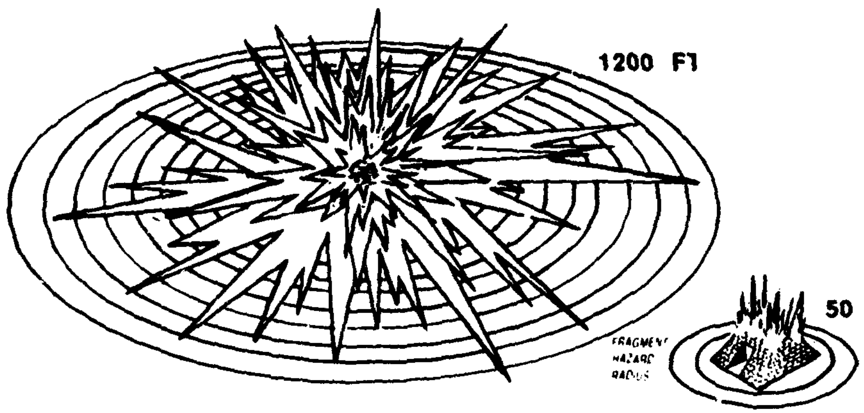
PURPOSE

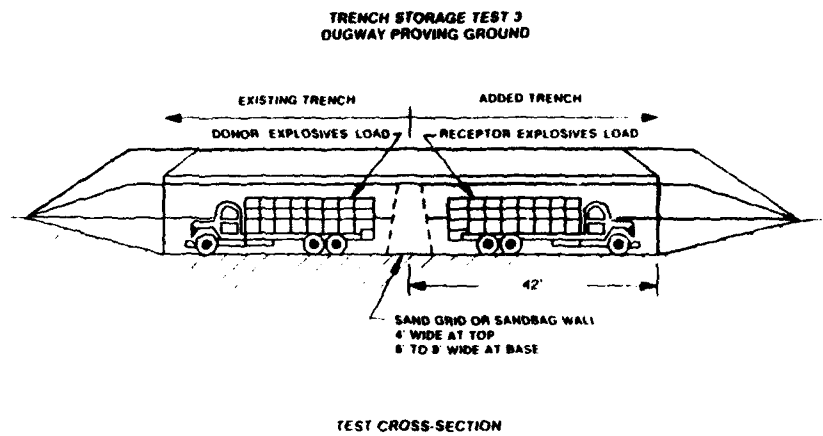
- PROVIDE AN OVERVIEW OF THE SAFELOAD PROGRAM
- EXPAND JOINT SERVICE COOPERATION AND PARTICIPATION

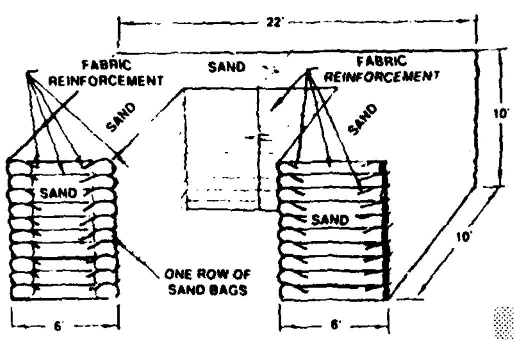
BACKGROUND

Safeload Program

PROVIDE SOLUTIONS TO REDUCE HAZARDS AND INCREASE SURVIVABILITY THROUGHOUT THE AMMUNITION LOGISTICS SYSTEM







GEOSYNTHETIC REINFORCED SAND WALLS

BENEFITS

- IMPROVES EXPLOSIVE SAFETY
- IMPROVES SURVIVABILITY FROM INCOMING FIRE AND ACCIDENTS
- REDUCES COSTLY REAL ESTATE ACQUISITIONS
- REDUCES COMPATIBILITY CONSTRAINTS
- REDUCES FRAGMENT HAZARD RADIUS
- REDUCES ENCUMBERED LAND
  - ELIMINATES EXPLOSIVE PROPAGATION
    - ELIMINATES COSTLY MCA PROJECTS
    - ELIMINATES VIOLATIONS/WAIVERS

CUSTOMER/ DELIVERABLES

- FIELD MACOMs, & DDESB
- TDP/DWGs/SPECs

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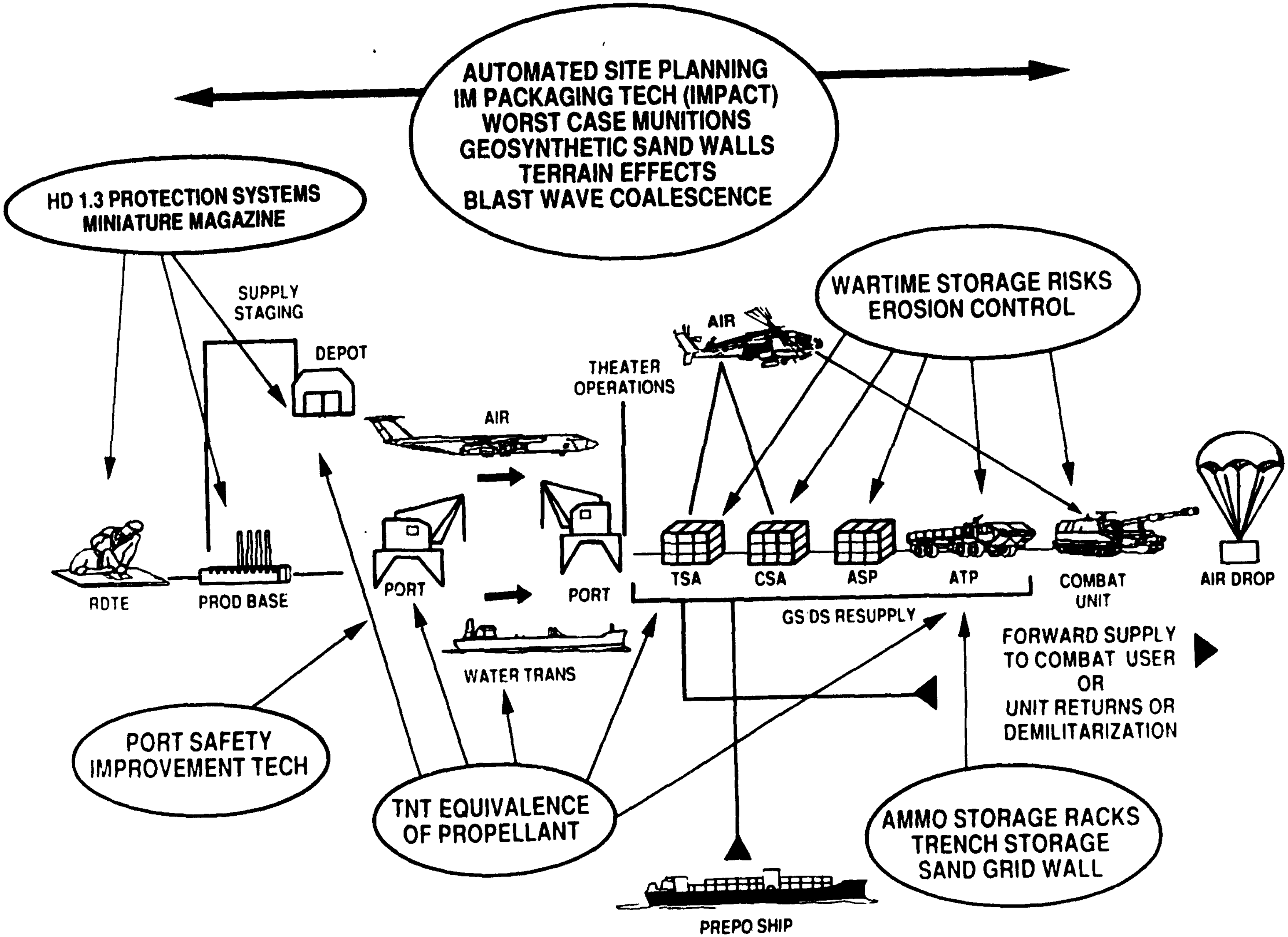
Safeload Program



EXPLOSIVES TESTING PROJECTS

ONGOING PROJECTS

WORST CASE MUNITIONS

ANALYSIS AND TESTS TO IDENTIFY "WORST CASE" MUNITIONS FOR USE IN PROPAGATION TESTING SO THAT FUTURE SAFELOAD SOLUTIONS WILL BE VALID FOR A WIDER RANGE OF MUNITIONS

JOINT PROGRAM

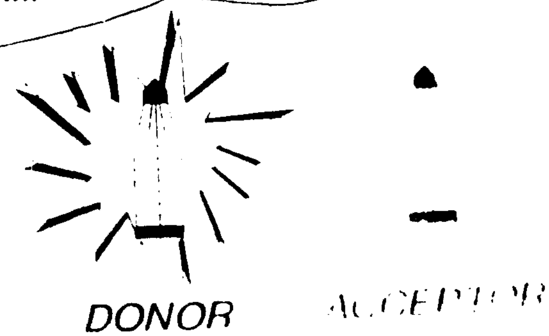
CONCURRENT NAVY EFFORT ADDRESSES NAVY MUNITIONS

SIDE BENEFITS

- BEING USED TO SUPPORT ARMY JUSTIFICATION TO RAISE EXPLOSIVE LIMITS ON NON-STD MAGAZINES
- NAVY HIGH PERFORMANCE MAGAZINE PROGRAM
- US/ROK UNDERGROUND AMMO STORAGE TECHNOLOGIES PROGRAM

DELIVERABLE: DoDESB APPROVED LIST OF WORST CASE MUNITION(S)

IMPLEMENTATION: WORST CASE MUNITIONS TO BE USED IN VALIDATION TESTING OF FUTURE SOLUTIONS

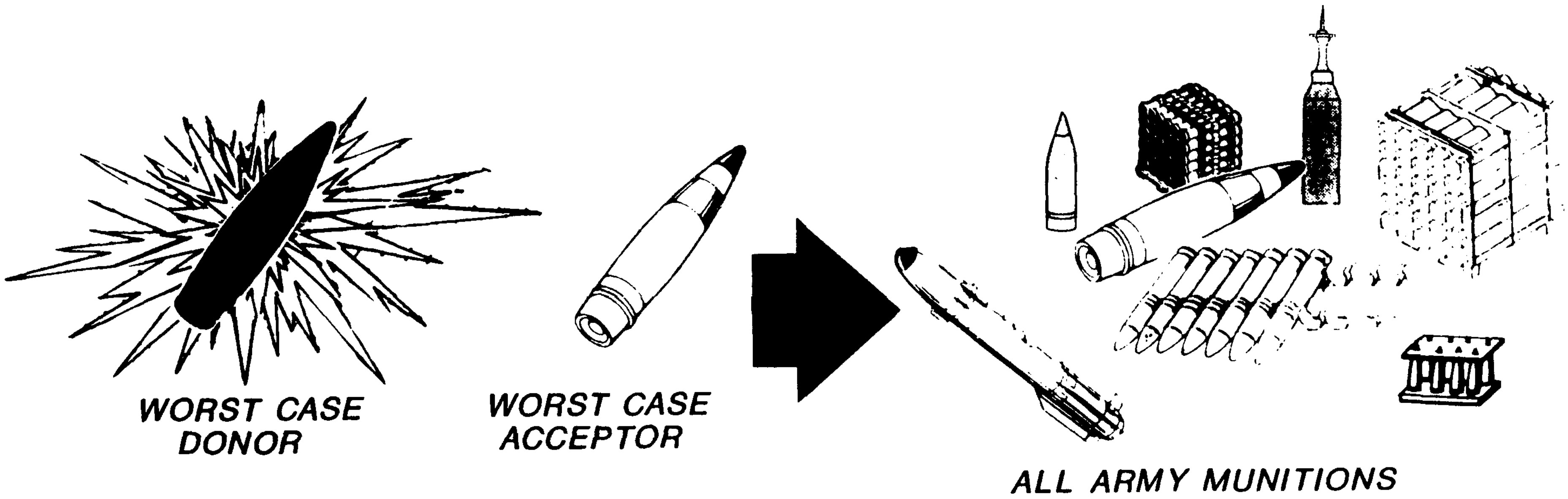


USER AND TECHNICAL COMMUNITY SUPPORT

- SUPPORTS USER NEED FOR LESS RESTRICTIONS
- TECHNICAL APPROACH DoDESB APPROVED
- PROJECT ENCOURAGED BY DoDESB, TCES, BRL, WES, NAVY, AND AIR FORCE

ONGOING PROJECTS

WORST CASE MUNITIONS

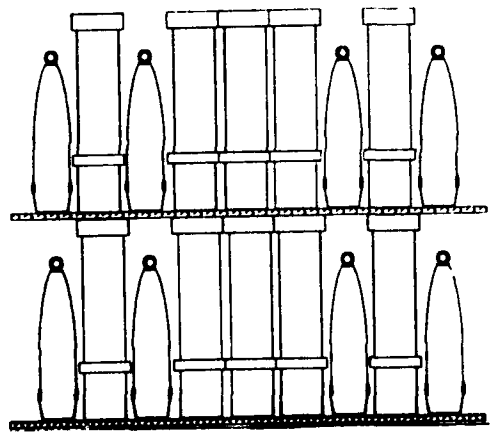


PROPAGATION TESTS USING THE WORST CASE DONOR AND ACCEPTOR MUNITIONS WILL PERMIT FUTURE SAFELOAD SOLUTIONS TO BE APPLICABLE TO ALL ARMY MUNITIONS

ONGOING PROJECTS

TNT EQUIVALENCE OF PROPELLANT

WHEN PROPELLANTS ARE STORED WITH HIGH EXPLOSIVES, DETERMINE THE ACTUAL CONTRIBUTION OF PROPELLANTS TO A DETONATION



PAYOFF

PROJECT RESULTS WILL REDUCE CALCULATED NET EXPLOSIVE WEIGHT ALLOWING MORE AMMO TO BE STORED OR REMOVE WAIVERS

DELIVERABLES: NUMERICAL FACTORS OF EQUIVALENCY FOR HIGH PAYOFF PROPELLANTS

IMPLEMENTATION: WILL BE INCLUDED IN EXPLOSIVE SAFETY REGULATIONS AND JHCS

USER SUPPORT

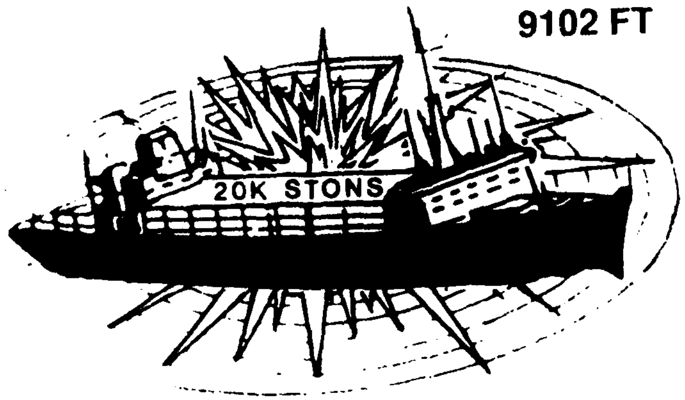
PROJECT REQUESTED BY USARJ

Safeload Program

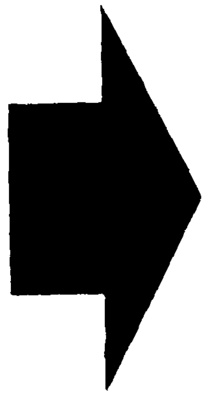
TNT EQUIVALENCE OF PROPELLANTS

OLD HAZARD ZONE 5975 ACRES

9102 FT

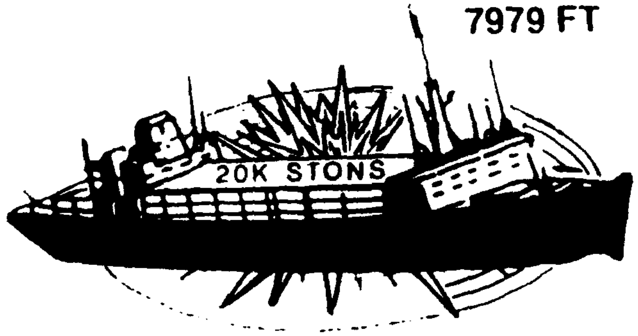


6 MIL LBS NET EXPLOSIVE WT (NEW)



NEW REDUCED HAZARD ZONE 4591 ACRES (23% REDUCTION)

7979 FT



4 MIL LBS NET EXPLOSIVE WT (NEW) (33% REDUCTION)

CUSTOMER/DELIVERABLES

- MACOMS
- REVISED N.E.W. FOR ARTY PROPELLANTS - FY94

BENEFITS

- REDUCED N.E.W. & HAZARD ZONE FROM MUNITIONS ABOARD ARMY PREPO SHIPS AND IN STORAGE

ONGOING PROJECTS

PERSONNEL PROTECTION FROM HAZARD DIVISION 1.3 REMOTE OPERATIONS

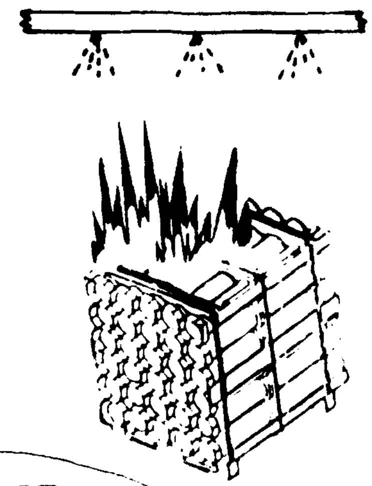
PROVIDE DESIGN CRITERIA FOR THE EVALUATION AND OPTIMIZATION OF EXISTING PROTECTION SYSTEMS FOR HAZARD DIVISION 1.3 REMOTE OPERATIONS (PROPELLANTS AND PYROTECHNICS)

JOINT FUNDING

DDESB FUNDING PHASE II - PASSIVE SYSTEMS

PAYOFF

- INCREASED SAFETY FOR REMOTE OPERATORS
- ELIMINATES FALSE ALARMS



DELIVERABLE:

- HANDBOOK WITH DESIGN CRITERIA FOR DIVIDING WALLS, BLOW-OUT PANELS, ULTRA HIGH SPEED DELUGE SYSTEMS, ETC

IMPLEMENTATION: DISTRIBUTION TO ARMY LOAD PLANTS AND DEPOTS AND INPUT IN REGULATIONS

USER SUPPORT

USATCES, DDESB, AMCCOM

Insensitive Munitions Packaging Technology (IMPACT)

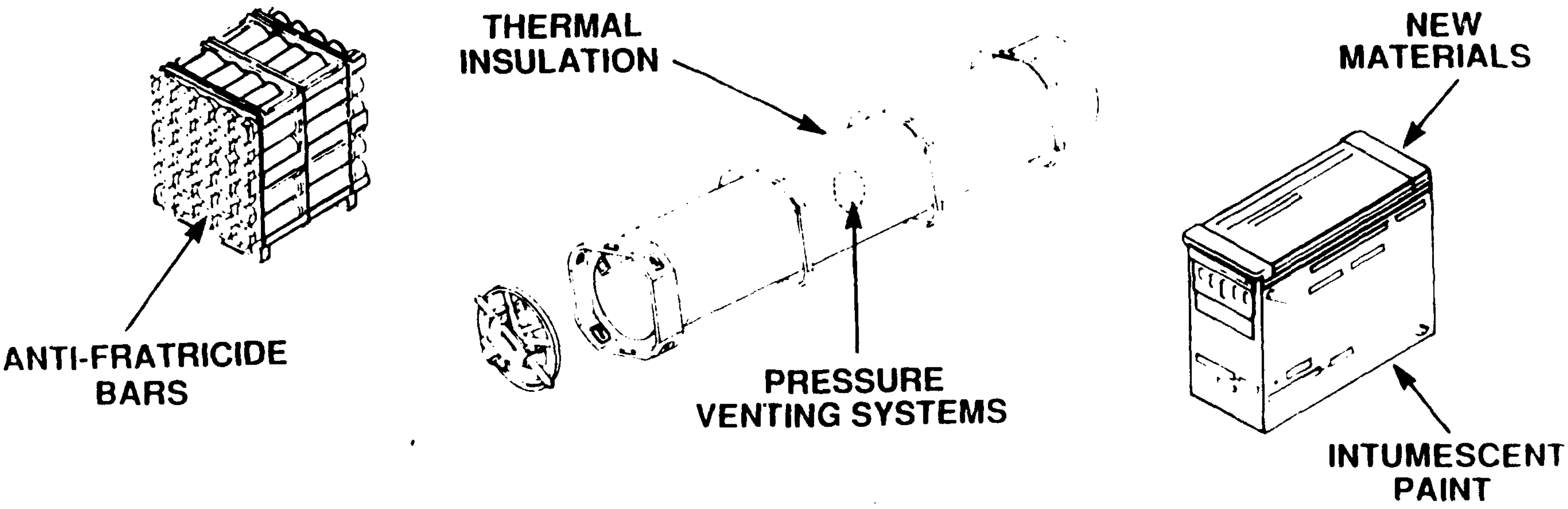
DEVELOP AND DEMONSTRATE NEW PACKAGING MATERIALS AND DESIGNS TO HELP ARMY MUNITIONS COMPLY WITH INSENSITIVE MUNITIONS REQUIREMENTS AND TO IMPROVE HAZARD CLASSIFICATION

CUSTOMER/DELIVERABLES

- AMMO DEVELOPERS/ARMY MACOMS
- TDP/DWGs/SPECs/DESIGN GUIDE

BENEFITS

- SUPPORTS INSENSITIVE MUNITIONS
- IMPROVES HAZARD CLASSIFICATION
- IMPROVES EXPLOSIVE SAFETY AND SURVIVABILITY OF AMMO DURING TRANSPORTATION AND STORAGE



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FUTURE PROJECTS

ZERO QUANTITY DISTANCE FOR HAZARD DIVISION 1.2

DETERMINE IF EXISTING MAGAZINES CAN STORE HAZARD DIVISION 1.2 AMMO WITH A ZERO OR REDUCED QUANTITY DISTANCE HAZARD ZONE

JOINT PROGRAM

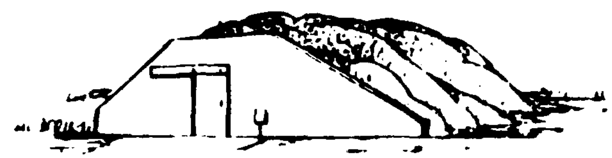
UK, DDESB, NSWC

PAYOFF

- INCREASES AMMO STORAGE CAPACITY
- REDUCES VIOLATIONS/WAIVERS

DELIVERABLE: DDESB APPROVED LIST OF MAGAZINES WHICH CAN ACCEPT HAZARD DIVISION 1.2 AMMO WITH ZERO OR REDUCED QD

IMPLEMENTATION: WILL BE INCLUDED IN EXPLOSIVE SAFETY REGULATIONS



USER SUPPORT

DDESB, USATCES

FUTURE PROJECTS

PREPOSITION SHIP QUANTITY DISTANCE REDUCTION

DETERMINE IMPROVED SHIP LOAD CONFIGURATIONS AND PERFORM TESTING TO REDUCE THE MAXIMUM CREDIBLE EVENT FOR THE ARMY'S PREPO SHIPS

PAYOFF

- INCREASES SAFETY
- REDUCES VIOLATIONS
- INCREASES NUMBER OF AMMO PORTS
- FACILITATES PREPO MAINTENANCE

DELIVERABLE: DDESB APPROVED AMMO CONFIGURATION WHICH REDUCES PREPO SHIP QUANTITY DISTANCES

IMPLEMENTATION: DURING PREPO YEARLY MAINTENANCE CYCLE

USER SUPPORT

RECOMMENDED BY HQ DA WORLDWIDE AMMO PORT SURVEY

FUTURE PROJECTS

CONVEYOR SPACING

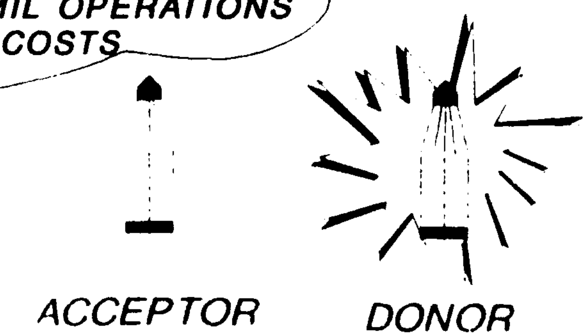
DETERMINE CONVEYOR SPACING DISTANCES FOR UNTESTED MUNITIONS BY ANALOGY TO THOSE PREVIOUSLY TESTED - FOR REMAINING UNTESTED MUNITIONS, DETERMINE REDUCED SPACING DISTANCES USING WORST CASE MUNITIONS AND SHIELDS

PAYOFF

- IMPROVED PRODUCTIVITY IN PRODUCTION, MAINTENANCE, AND DEMIL OPERATIONS
- REDUCED TESTING COSTS

DELIVERABLE: CONVEYOR SPACING DISTANCES FOR PRIORITIZED MUNITIONS AND REDUCED SPACING DISTANCES USING SHIELDS FOR ALL UNTESTED ARMY MUNITIONS

IMPLEMENTATION: DISTRIBUTION TO ARMY LOAD PLANTS AND DEPOTS AND INPUT IN REGULATIONS



USER SUPPORT

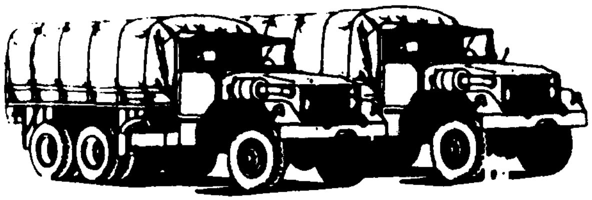
AMCCOM SAFETY, USATCES
AMCCOM MAINTENANCE

PROJECTS WHICH USE COMPUTER CODES BASED ON EXPLOSIVES TESTING

ONGOING PROJECTS

WARTIME STORAGE RISKS

RISK ANALYSIS FOR AMMO STORAGE VIOLATIONS IN COMBAT EMERGENCIES WHEN ADEQUATE LAND IS NOT AVAILABLE



PAYOFF

HELPS COMMANDERS MAKE BEST DECISIONS TO MINIMIZE AMMO STORAGE RISKS

DELIVERABLES: TABLES AND GRAPHS SHOWING INCREASES IN LEVEL OF RISK FOR QD VIOLATIONS

IMPLEMENTATION: WILL BE INCLUDED IN DA PAMPHLET 385-64

USER SUPPORT

TRADOC, FORSCOM, USAREUR, EUSA, USARPAC, USARSO, OMMCS
HQ AMC SAFETY

ONGOING PROJECTS

MINI-MAGAZINE

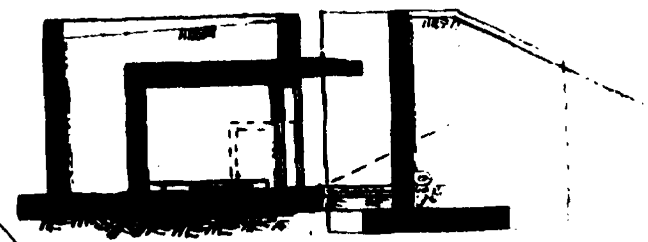
TWO DESIGNS OF INEXPENSIVE SMALL EARTH COVERED MAGAZINES (150 LBS AND 400 LBS NEW) FOR STORAGE OF MUNITIONS (INCLUDING NON-COMPATIBLE AND HD 1.2) WITH REDUCED QUANTITY DISTANCE REQUIREMENTS

JOINT PROGRAM

- SECRET SERVICE TO FUND ADDITIONAL 500 AND 5000 LB DESIGNS
- USES DOE/DDESB DEVELOPED COMPUTER CODES
  - BASED ON NAVY DESIGN

PAYOFF

150 LB NEW DESIGN REDUCES QUANTITY DISTANCE FROM 1250 FT TO 186 FT



DELIVERABLE: TDP WITH CONSTRUCTION INFORMATION, DRAWINGS, AND SPECS

IMPLEMENTATION: DISTRIBUTION TO ARMY MACOMS AND INCORPORATION IN EXPLOSIVES SAFETY REGULATION AND CORPS OF ENGINEERS DATA BASE

USER SUPPORT

TRADOC'S SECOND HIGHEST PRIORITY
FORSCOM, USAREUR, EUSA, USARSO, USASOC, OMMCS, HQ AMC SAFETY, AMCCOM

ONGOING PROJECTS

EFFECT OF TERRAIN ON FRAGMENT DISTANCE

DETERMINE THE EFFECT OF NATURAL TERRAIN (CLIFFS, FORESTS, HILLS, ETC) ON FRAGMENTATION DISTANCES TO REDUCE INHABITED BUILDING DISTANCE REQUIREMENTS

DELIVERABLES: FINAL REPORT WITH DATA AND ANALYSIS TO JUSTIFY REDUCED QUANTITY DISTANCE

IMPLEMENTATION: DoDESB APPROVAL OF Q-D REDUCTION

USER SUPPORT

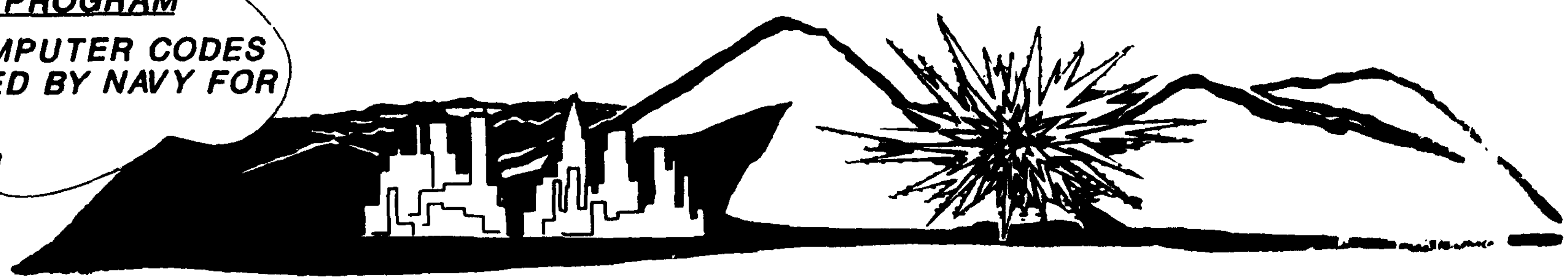
PROJECT REQUESTED BY USARJ

PAYOFF

PROJECT WILL TAKE ADVANTAGE OF NATURAL BUFFERS AND ALLOW MORE AMMUNITION TO BE STORED OR REMOVE WAIVERS

JOINT PROGRAM

- USES COMPUTER CODES DEVELOPED BY NAVY FOR DoDESB



ONGOING PROJECTS
BLAST WAVE COALESCENCE

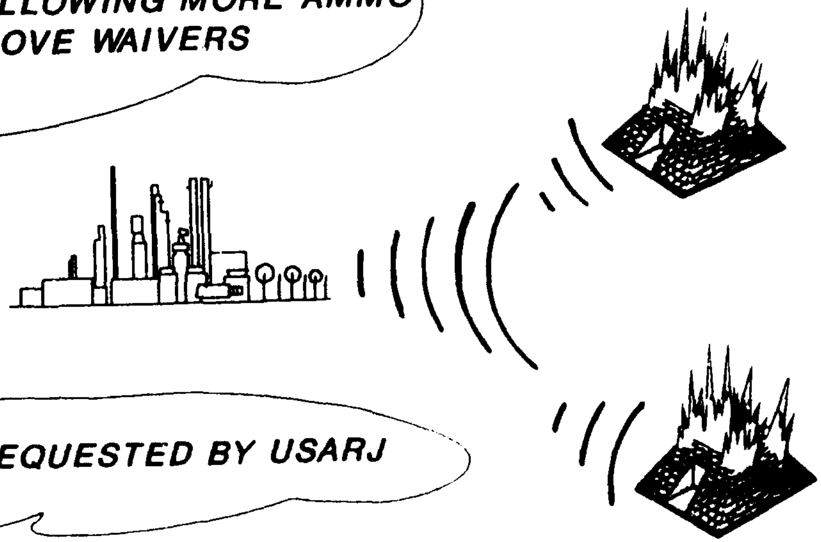
DEVELOP METHODOLOGY TO DETERMINE IF BLAST WAVES WILL COALESCE GIVEN NET EXPLOSIVE WEIGHT AND SEPARATION DISTANCE OF UNEQUAL STACKS OF AMMO STORED CLOSER THAN ALLOWED

PROJECT RESULTS MAY REDUCE CALCULATED MAXIMUM CREDIBLE EVENT ALLOWING MORE AMMO TO BE STORED OR REMOVE WAIVERS

DELIVERABLES: FIELD USABLE TABLES CHARTS AND SIMPLE CALCULATIONS

IMPLEMENTATION: WILL BE INCLUDED IN EXPLOSIVE SAFETY REGULATIONS

PROJECT REQUESTED BY USARJ



WRAP-UP

SAFELOAD USES AND GENERATES EXPLOSIVES TESTING DATA TO IMPROVE SAFETY THROUGHOUT THE AMMUNITION LOGISTICS SYSTEM

SUMMARY

THE SAFELOAD PROGRAM PROVIDES:

- IMPROVED SAFETY
- IMPROVED SURVIVABILITY
- REDUCED QUANTITY-DISTANCE
- ELIMINATION OF WAIVERS/VIOLATIONS
- RISK REDUCTION

RESULTING IN A BETTER CAPABILITY TO SAFELY SUSTAIN OUR FORCES

WORST CASE ACCEPTOR

U.S. ARMY RESEARCH LABORATORY
WEAPONS TECHNOLOGY DIRECTORATE
TERMINAL EFFECTS DIVISION
EXPLOSIVE TECHNOLOGY BRANCH

ADDRESS:
U. S. ARMY RESEARCH LABORATORY
ATTN: AMSRL-WT-TB DR. ROBERT FREY
ABERDEEN PROVING GROUND, MD. 21005-5066

POC: DR. ROBERT FREY (410) 278-6206 DSN 298-6206
MR. ONA LYMAN (410) 278-6543 DSN 298-6543

WORST CASE ACCEPTOR

SPONSOR: PM for AMMUNITION LOGISTICS
SAFELOAD EXPLOSIVE SAFETY PROGRAM

SAND GRID WALLS

AMMUNITION STORAGE RACKS

CONEX CONTAINER STORAGE

MANY OTHER SIMILAR PROGRAMS

PROGRAMS GENERALLY WERE APPLICATION SPECIFIC

APPROVAL GRANTED FOR SPECIFIC AMMUNITION & SCENARIOS

Worst Case Acceptor Program

Executive Summary

Dr. Robert Frey
Mr. Ona Lyman
U.S. Army Research Laboratory
Attn: AMSRL-WT-TB
Aberdeen Proving Ground, MD 21005-5066

The sponsor for this work was the PM for Ammunition Logistics, Safeload Program. The sponsor has successfully developed a variety of techniques for improving the safety of ammunition handling. In general these were all application specific and approval for there use was limited to munitions used in proof tests. The motivation for this program was to determine if there was an ammunition item that was more sensitive to sympathotic detonation than any other, and if there was then argue that tests performed with this ammunition item would be valid for other items known to be less sensitive.

Five mechanisms of initiation were considered appropriate for this study. They are, 1. Fragment impact or short duration shock loading. 2. Long duration shock loading. 3. Crushing. 4. Multiple impact/shock loading. 5. Deflagration to detonation transition. For these tests it is assumed that barriers will be used that will eliminate fragment threats in any application, and deflagration to detonation transitions are beyond the scope of effort available. The remaining mechanisms can be evaluated with two sets of tests because it is only necessary to determine which item is the worst case.

Candidate selection is critical to success of this effort. The criteria used were: 1. sensitivity of explosive fill 2. representation of different classes of items 3. experience from similar tests 4. ease of testing and 5. net explosive weight under 100 pounds. More than 600 ammunition items were considered and the following were selected. 1. M107 155 mm projectile comp B filled 2. M483 155 mm projectile w/A5 filled submunitions 3. TOW II motor 4. M865 ctg. LKL propellant fill. 5. generic 105 mm ctg. w/m43 propellant fill. 6. M2A3 demolition chg. with comp B fill. The Navy ran similar tests with Mark 82 bombs w/H6 fill.

Two tests were made on each munition. The first allowed a 4" thick flyer plate to strike the test item at moderate velocity and the test item and plate then struck a solid backstop after travelling about 30 cms. Reactions always occurred at the second impact. The second test used a similar thick flyer plate but five alternating layers of steel and polyethylene were between the flyer plate and the test item, which was in contact with a solid backstop. This provides crushing of the test item, but does not produce a shockwave in the test item.

Two reactions were observed in these tests, either an explosion or burning of the reactive material. The M2A3 demolition charge proved to be the more sensitive of the test items. It exploded in the double impact tests with a plate velocity of 24 meters per second. The M483 was the next most sensitive based on an explosive reaction, again in the double impact test with a velocity of 49 Meters per second. The propellant items all produced a burn at velocities of 30 Meters per second. The double impact test produced reactions at lower velocities than did the crush tests for the same test items.

THE OBJECTIVE

TO IDENTIFY A "WORST CASE ACCEPTOR" TO BE USED IN MEDIUM TO LARGE SCALE SYMPATHETIC DETONATION TESTS. A SUCCESSFUL TEST WITH THE "WORST CASE ACCEPTOR" WOULD PERMIT THE RESULTS TO BE APPLIED TO A LARGE NUMBER OF MUNITIONS.

WHY NOT ONE ON ONE TESTING?

THE SIZE OF THE ROUNDS MAY INFLUENCE THE RESULTS IN A WAY THAT ARE NOT REPRESENTATIVE OF LARGE SCALE EVENTS.

IF THE SAME DONOR IS USED.

* A SMALL ROUND MAY BE CRUSHED TO A GREATER EXTENT.
* A LARGE ROUND MAY SEE A LONGER DURATION SHOCK.
* SHOCK DURATION AND TOTAL IMPULSE MAY BE MUCH LESS THAN THEY WOULD BE IN A LARGE SCALE EVENT.

WHY IT IS DIFFICULT

THERE ARE A LOT OF POTENTIAL CANDIDATES:

* THE USADACS HANDBOOK LISTS 566 HAZARD CLASSIFICATION 1.1 ITEMS!

* 1.3 ITEMS CAN'T BE EXCLUDED (WHEN LOADED OVER LARGE AREAS, SOME ARE DETONABLE AND SENSITIVE).

THERE ARE A NUMBER OF POSSIBLE MECHANISMS. WHAT IS WORST FOR ONE ISN'T NECESSARILY WORST FOR ANOTHER.

EXAMPLE OF MECHANISTIC COMPLEXITY

US ARMY LABORATORY COMMAND

BALLISTIC RESEARCH LABORATORY

AMMUNITION COMPARTMENT TESTS:

120 MM WH + BUFFER IN LIGHT COMPARTMENT	NO PROPAGATION
120 MM WH + BUFFER IN STRONG COMPARTMENT	PROPAGATION
120 MM WH (WITHOUT PROPELLANT) + IMPROVED BUFFER IN HEAVY COMPARTMENT	NO PROPAGATION
120 MM WH (WITH PROPELLANT) + IMPROVED BUFFER IN HEAVY COMPARTMENT	PROPAGATION

EXAMPLE OF MECHANISTIC COMPLEXITY

SANDBAG BUFFER TESTS WITH COMP B LOADED M107 PROJECTILES:

WITH STEEL PLATE BEHIND ACCEPTORS: PROPAGATION

WITH SANDBAGS BEHIND ACCEPTORS: NO PROPAGATION

EXAMPLE OF MECHANISTIC COMPLEXITY

COMPARISON OF TWO EXPLOSIVES ON A GAP TEST AND A BUFFERED SYMPATHETIC DETONATION TEST:

	CRITICAL BUFFER THICKNESS (NOL LARGE SCALE GAP TEST) MM	CRITICAL BUFFER THICKNESS (BUFFERED SYM. DET. TEST IN M1 HARDWARE) MM
COMP B	51	9.6
RX-08-EL	70	0

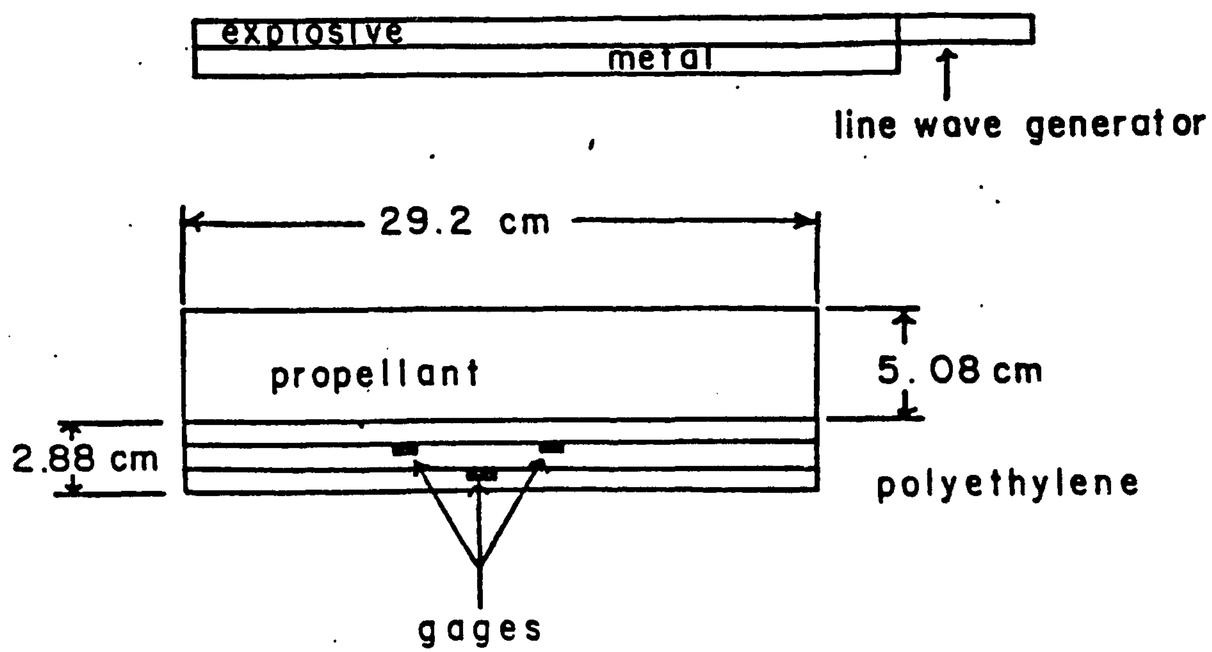
EXAMPLE OF MECHANISTIC COMPLEXITY

US ARMY
LABORATORY COMMAND

BALLISTIC RESEARCH LABORATORY

SHOCK INITITATION OF M30 (A HAZARD CLASS 1.3 GUN PROPELLANT):

Plane Wave Experiment



Less than 7 kbar shock pressure causes a reaction which produces pressures close to those expected from detonation.

WORST CASE ACCEPTOR

POSSIBLE MECHANISMS

1. FRAGMENT IMPACT AND SHORT DURATION SHOCK DUE TO IMPACT OF THE FRAGMENTS OR EXPANDING CASE FROM A DONOR MUNITION.

2. LONG DURATION SHOCK DUE TO *IMPACT OF* BUFFER MATERIAL. THERE CAN BE CROSS-OVERS IN THE RELATIVE SENSITIVITY OF MATERIALS TO SHORT AND LONG DURATION SHOCK.

3. CRUSHING (MASSIVE DEFORMATION OVER TIMES LARGE COMPARED TO SHOCK INITIATION TIMES).

4. MULTIPLE SHOCK (ONE SHOCK FROM IMPACT OF BARRIER, ANOTHER FROM IMPACT ON ANOTHER ROUND OR REAR WALL).

5. DEFLAGRATION TO DETONATION TRANSITION AS A RESPONSE TO LONG DURATION OVERPRESSURES.

WORST CASE ACCEPTOR

SIMPLIFICATIONS

* DONT CONSIDER "ROUND SPECIFIC" PROBLEMS LIKE MUNITION RACKS.

* ASSUME THAT ALL PRIMARY FRAGMENTS ARE STOPPED BY A BUFFER.

* IGNORE BOMBS & LARGE ROCKET MOTORS WITH NEW GREATER THAN 100 LBS.

* DRASTICALLY LIMIT NUMBER OF CANDIDATES ON BASIS OF THE SENSITIVITY OF THE FILL AND EXPERIENCE.
  - TEST AT LEAST ONE GUN PROPELLANT.
  - TEST AT LEAST ONE BARE DEMOLITION CHARGE.
  - TEST AT LEAST ONE HEAVILY CONFINED CHARGE.

* TEST ONLY UNFUSED ROUNDS.

WORST CASE ACCEPTOR

CANDIDATE SELECTION

CRITERIA:

* SENSITIVITY OF EXPLOSIVE FILL
* REPRESENTATIVE ITEMS
* NET EXPLOSIVE WEIGHT PER ITEM
* EXPERIENCE
* TESTABILITY

WORST CASE ACCEPTOR

SELECTED CANDIDATES

1. M107 155 mm PROJECTILE COMP. B FILL
2. M483 155 mm PROJECTILE W/SUBMUNITIONS (A5 FILL)
3. TOW II MOTOR
4. M865 CARTRIDGE LKL PROPELLANT FILL
5. GENERIC 105 mm CTG. CASE WITH M43 PROPELLANT FILL
6. M2A3 CHARGE, DEMO., SHAPED, HOLE DIGGER (COMP. B [redacted])

A. M67 HAND GRENADE

B. MLRS (MINSMOKE ROCKET MOTOR AND SUBMUNITIONS

* MARK 82 BOMB H-6 EXPLOSIVE FILL (NAVY FUNDED TEST)

WORST CASE ACCEPTOR

TEST PROGRAM

* ASSUME DONOR FRAGMENTS WILL BE INTERCEPTED.
* USE THICK FLYER PLATES TO GIVE LONG SHOCK DURATION.
* USE STEEL FLYER PLATES TO GIVE LARGE MASS FOR CRUSHING.
* USE PLATE LATERAL DIMENSIONS LARGER THAN TEST ITEM.
* SINGLE IMPACT EVENTS WILL BE OBSERVED AS PROMPT EVENTS IN DOUBLE IMPACT TESTS.

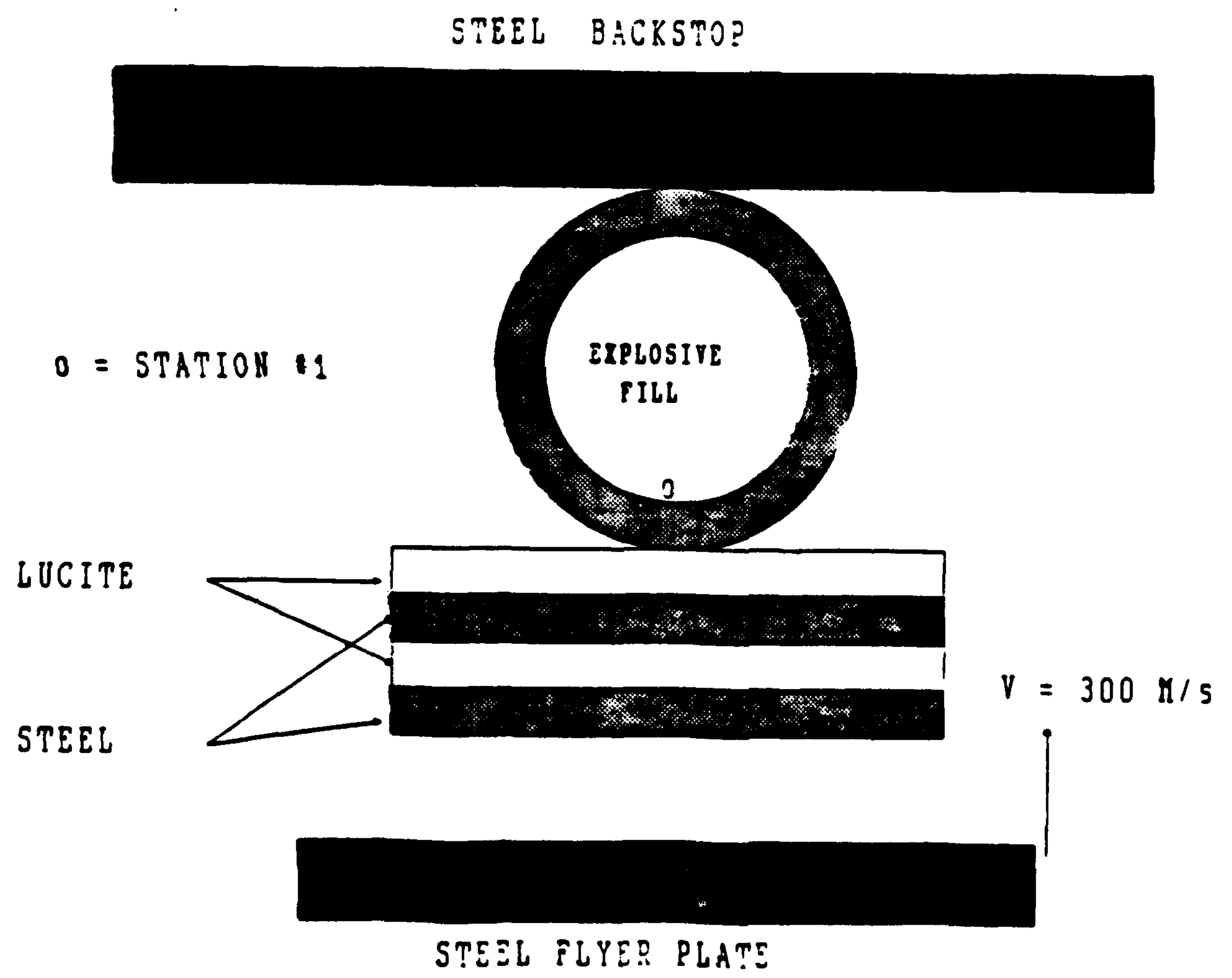
TESTS PERFORMED:

1. NONSHOCK CRUSHING OF TEST ITEM

2. DOUBLE IMPACT
   - A. FIRST IMPACT TO WEAK FOR PROMPT INITIATION.
   - B. SECOND IMPACT IS ON A SOLID ANVIL FOLLOWED BY FLYER PLATE IMPACTING THE TEST ITEM.

WORST CASE ACCEPTOR

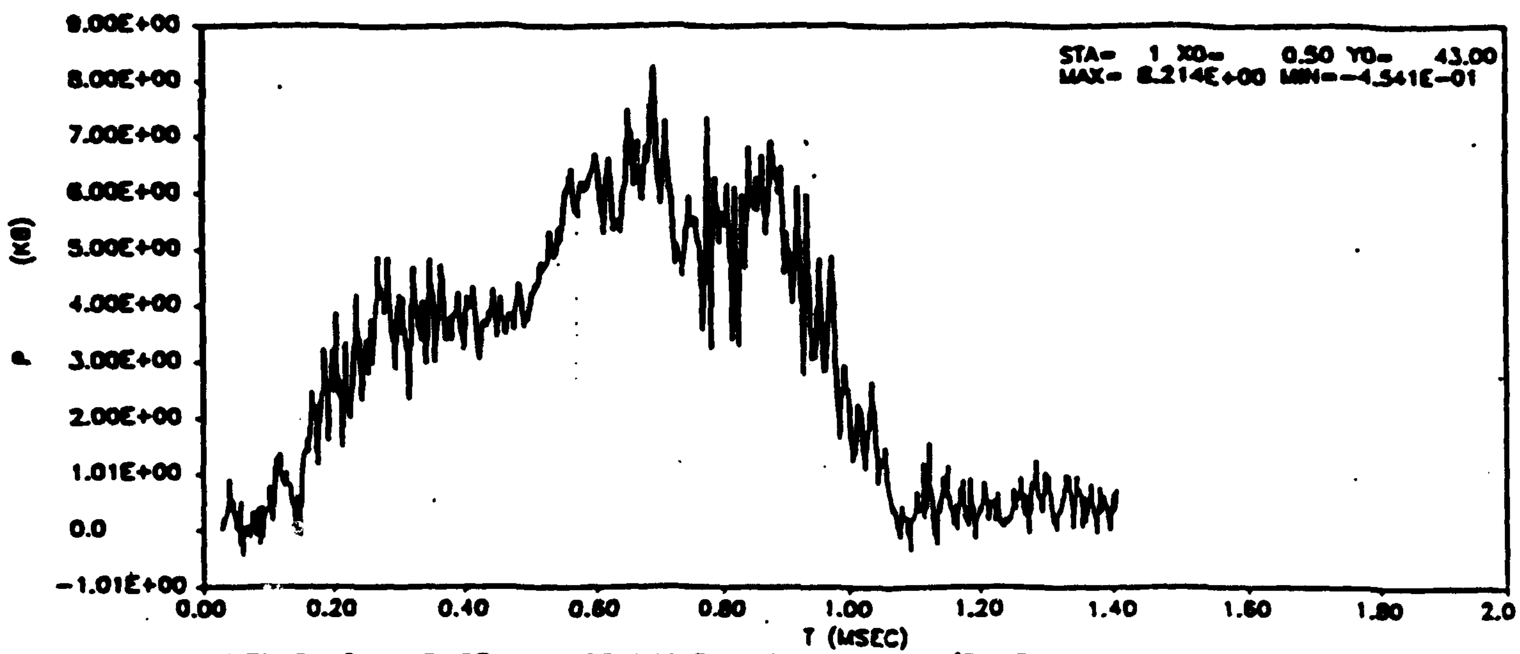
COMPUTATION LAYOUT for CRUSH CONFIGURATION



WORST CASE ACCEPTOR

COMPUTATION, CRUSH COFIGURATION
PRESSURE vs TIME @ STATION #1

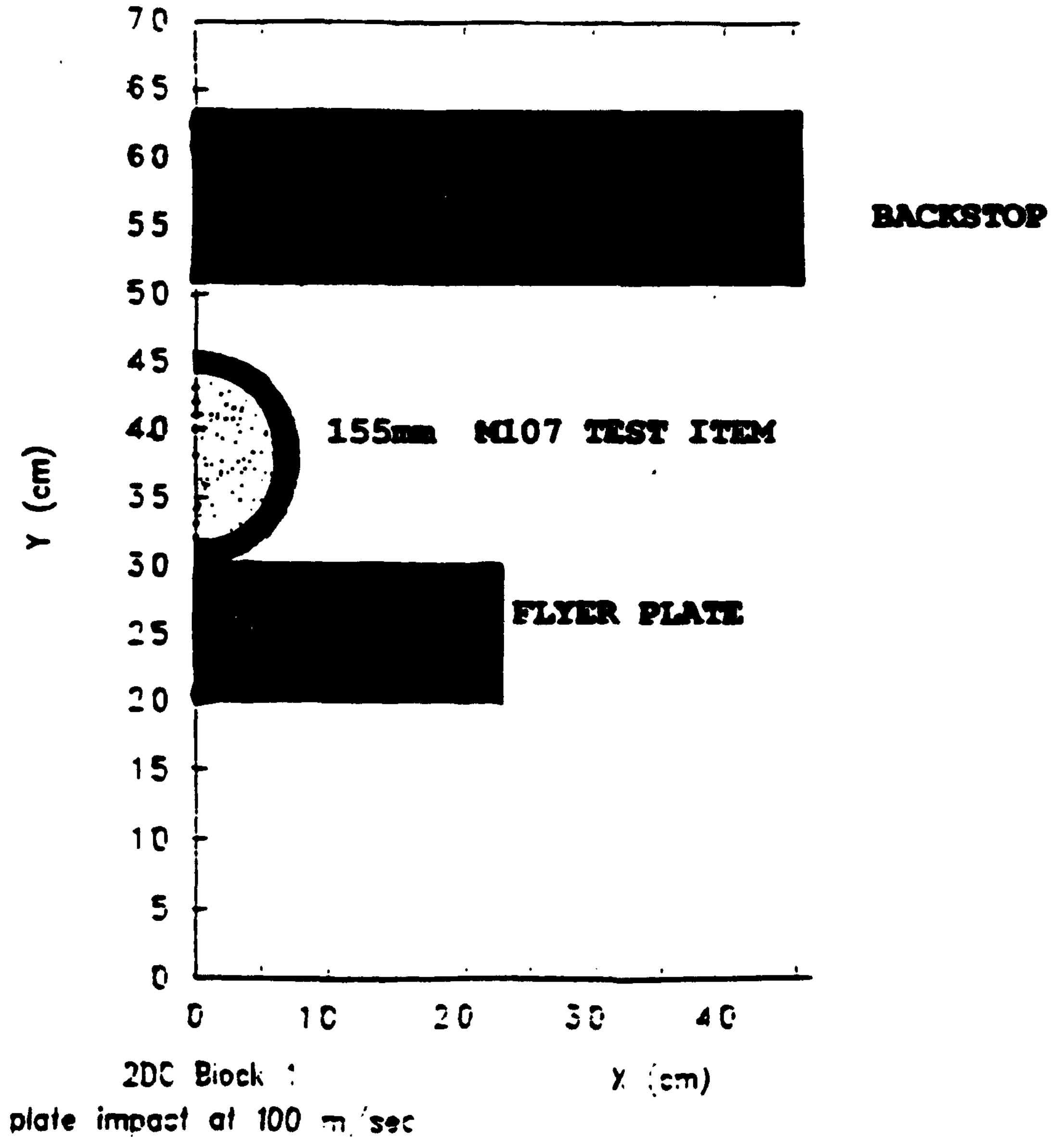
BUFFER COMBINATION 1" STEEL, 1" LUCITE, 1" STEEL, 1" LUCITE



STEEL PLATE IMPACT OF 155 MM ROUND AT 300 M/S Problem 1.6000

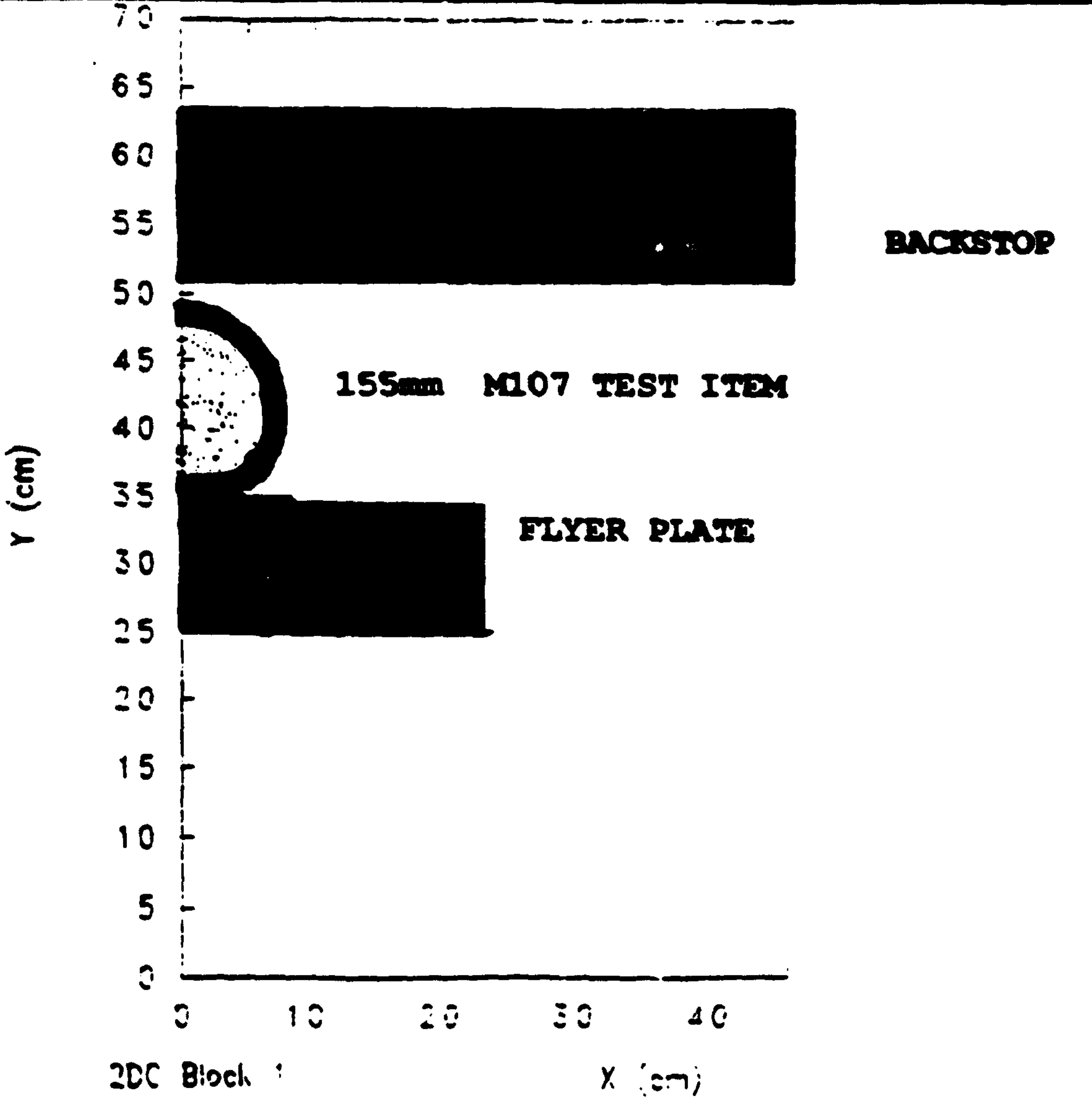
WORST CASE ACCEPTOR

COMPUTATION DOUBLE IMPACT TIME = 0 MILLISEC.



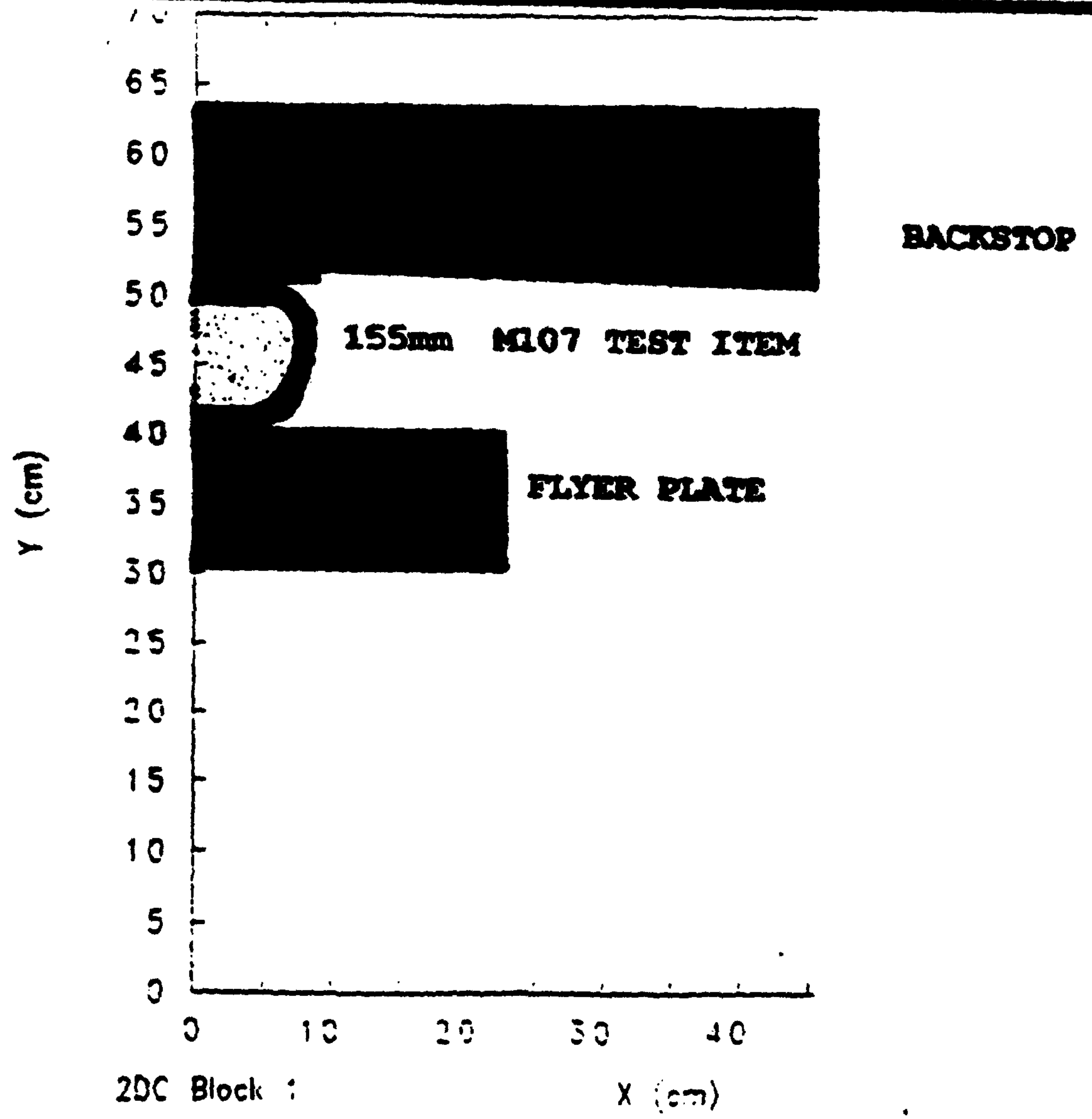
WORST CASE ACCEPTOR

COMPUTATION DOUBLE IMPACT TIME = 0.5 MILLISEC.



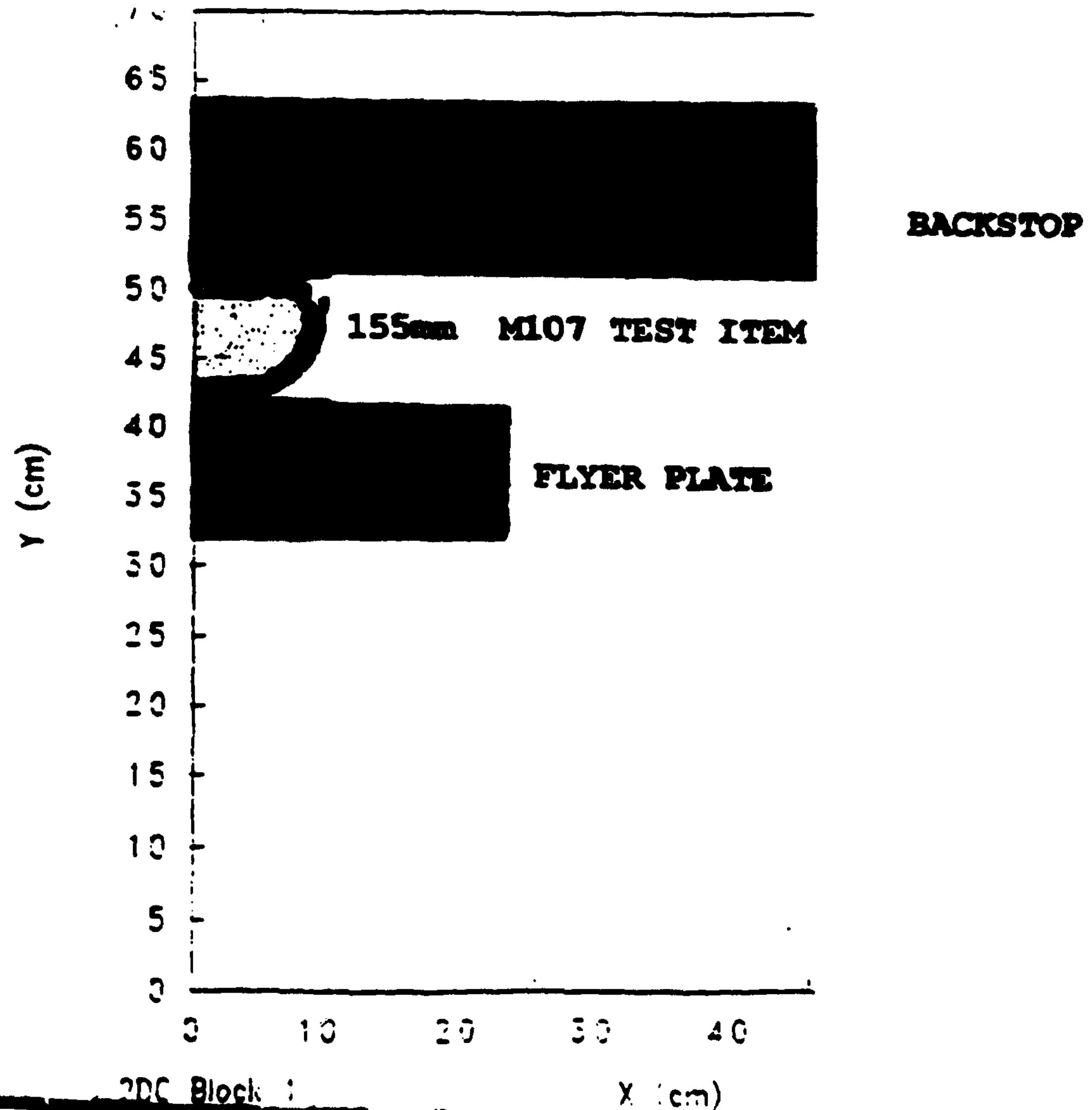
WORST CASE ACCEPTOR

COMPUTATION DOUBLE IMPACT TIME = 1.1 MILLISEC.



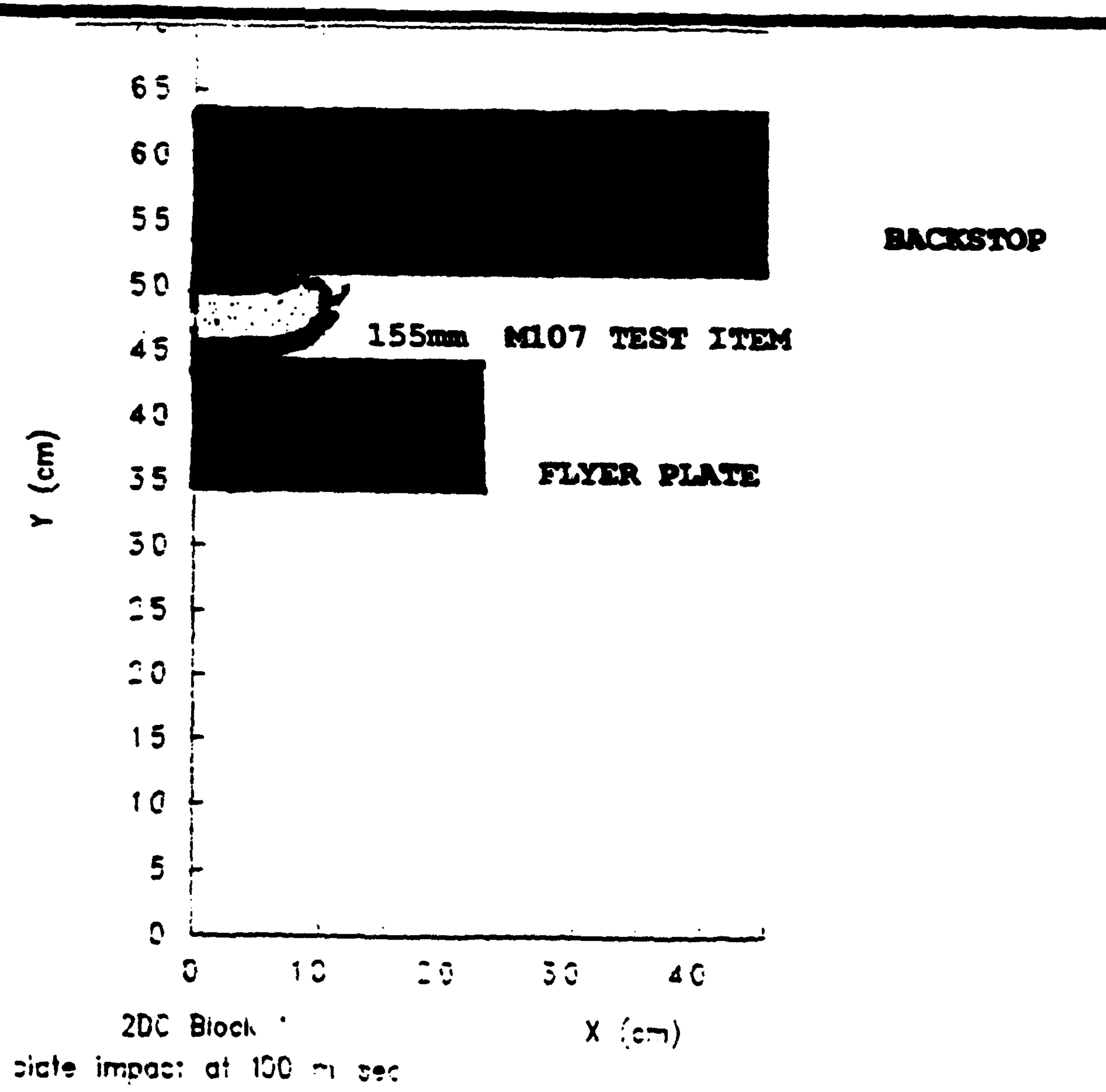
WORST CASE ACCEPTOR

COMPUTATION DOUBLE IMPACT TIME = 1.3 MILLISEC.



WORST CASE ACCEPTOR

COMPUTATION DOUBLE IMPACT TIME = 1.6 MILLISEC.



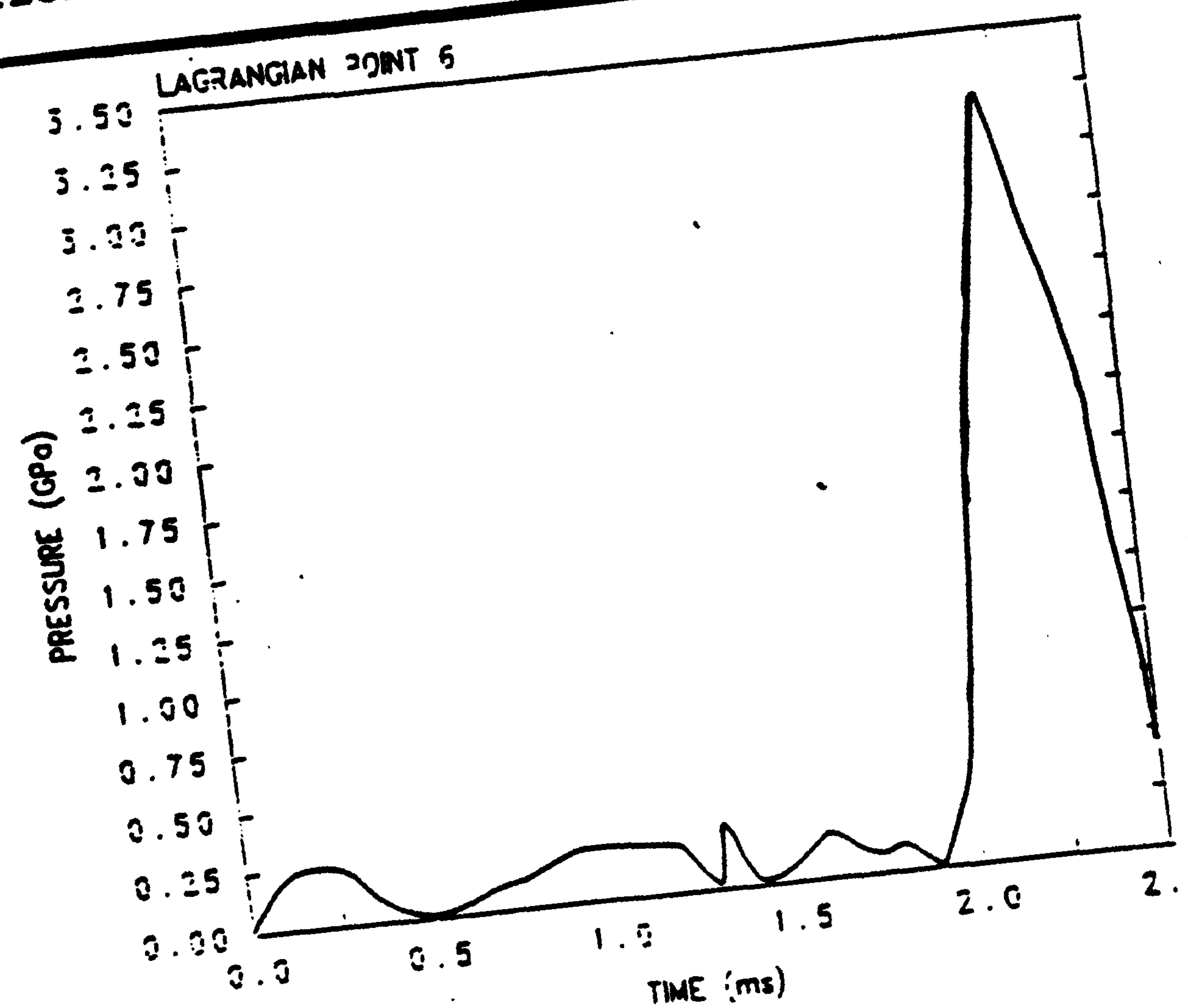
WORST CASE ACCEPTOR

COMPUTATION DOUBLE IMPACT PRESSURE vs TIME

155 mm M107 ROUND
SIMULATION

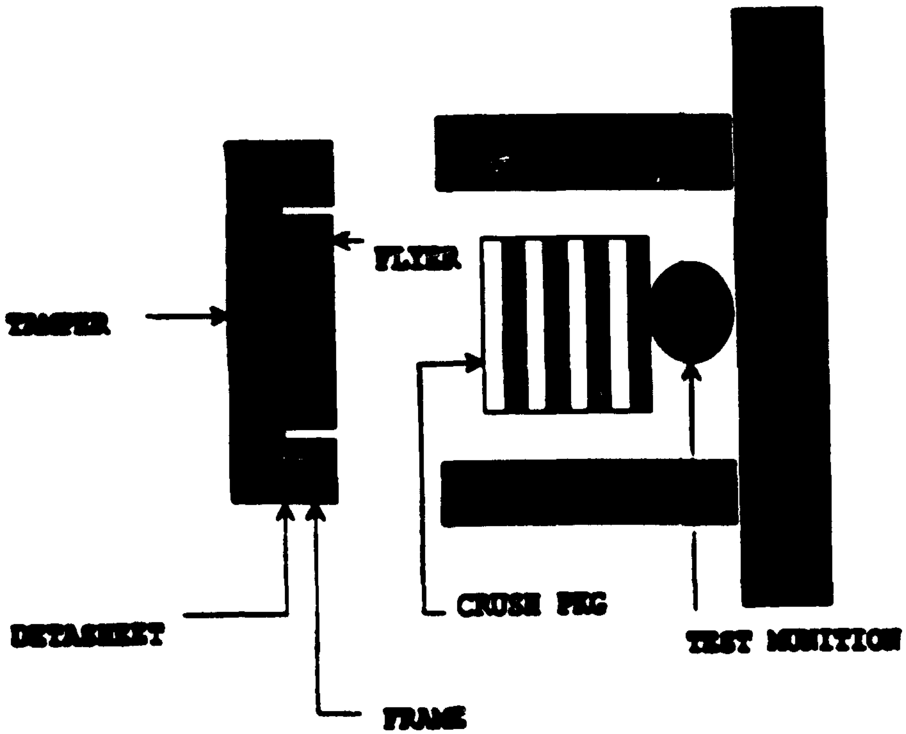
PLATE IMPACT
VELOCITY = 100 M/s

LAGRANGIAN POINT 6
MIDWAY BETWEEN
BACKSTOP AND CENTER
OF ROUND



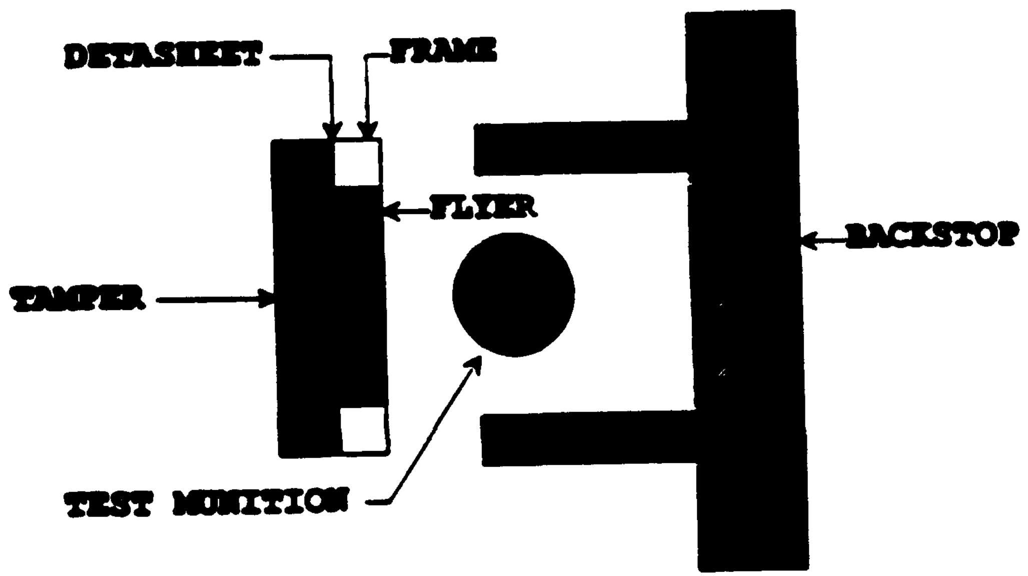
WORST CASE ACCEPTOR

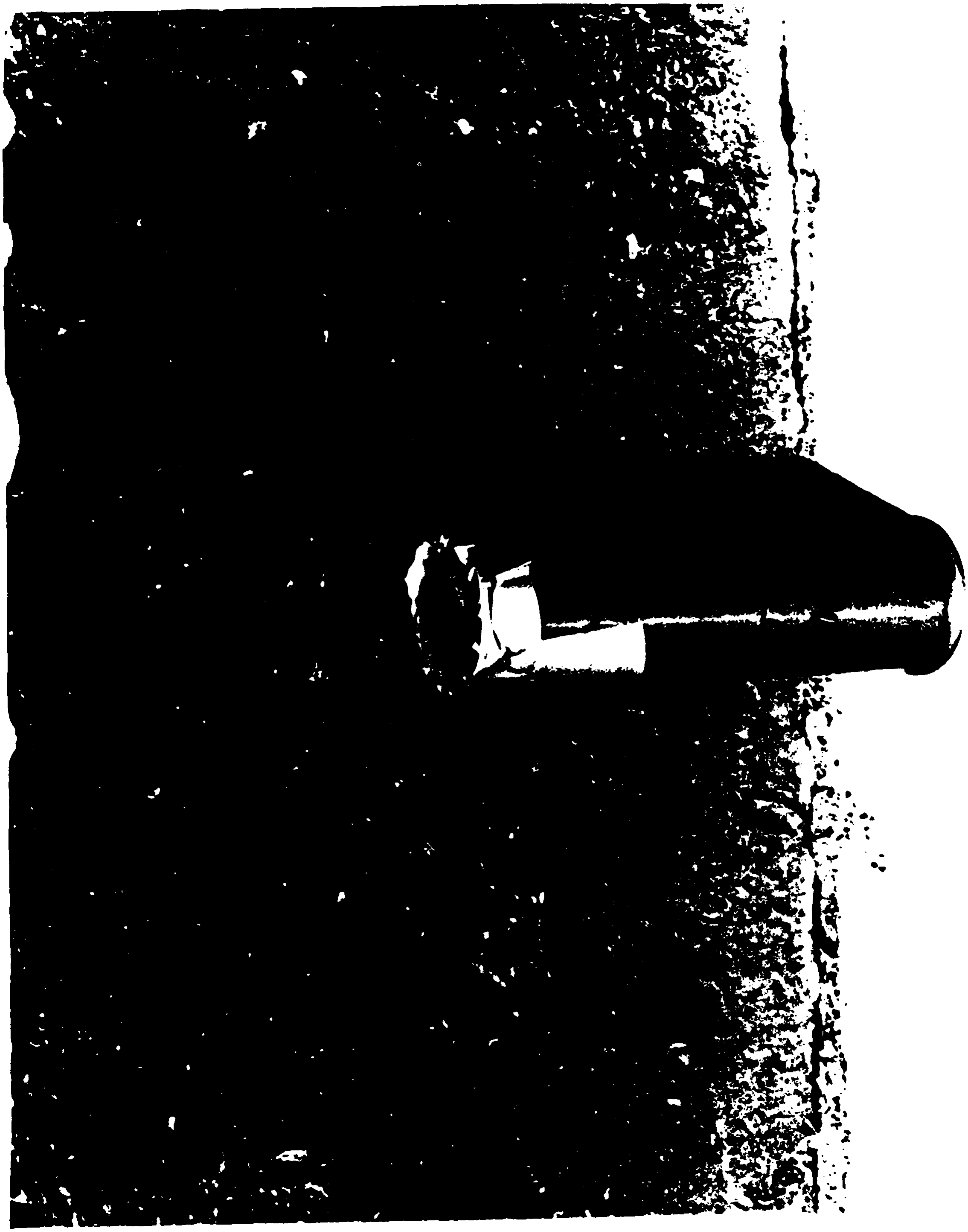
CRUSH TEST SETUP

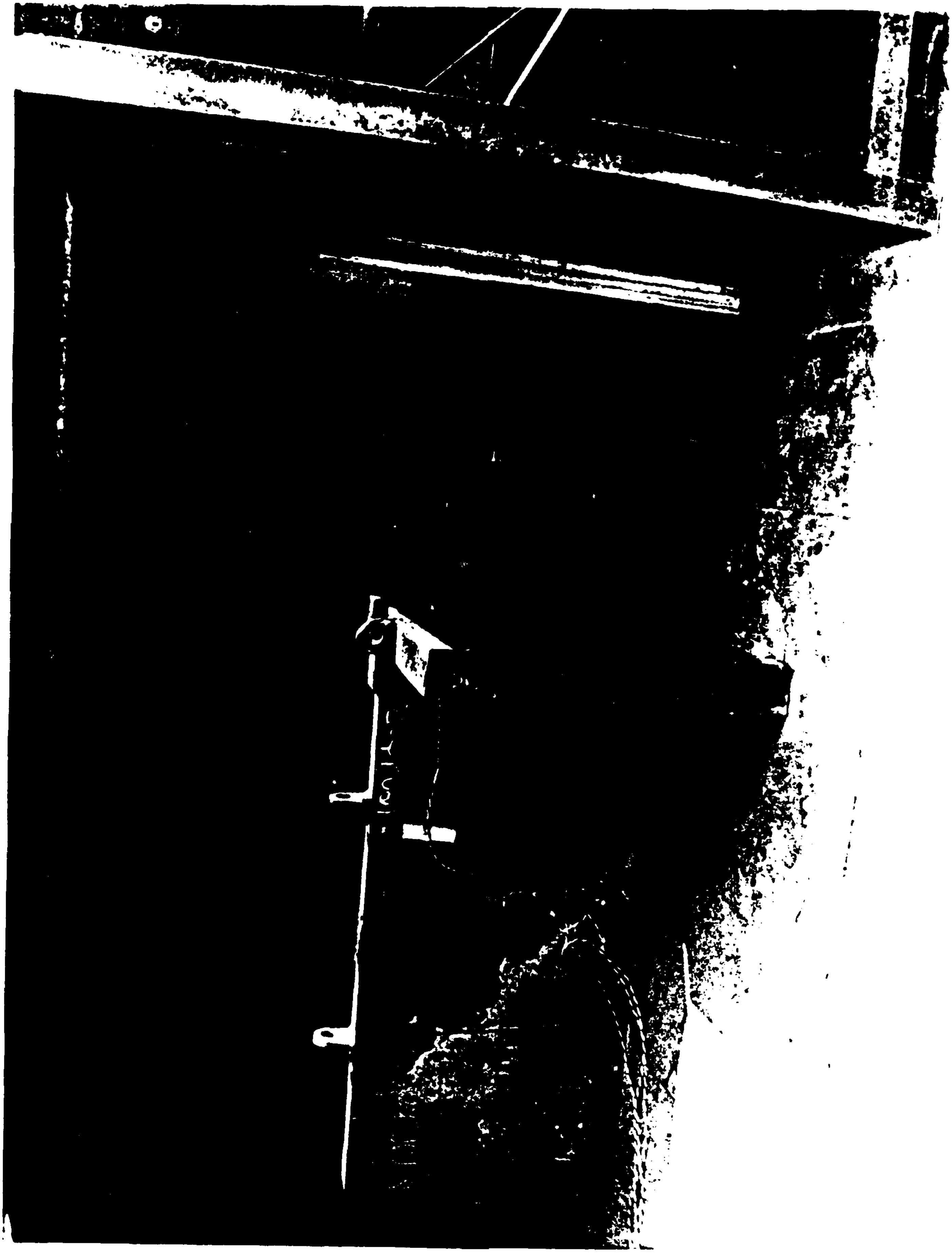


WORST CASE ACCEPTOR

DOUBLE IMPACT TEST SETUP







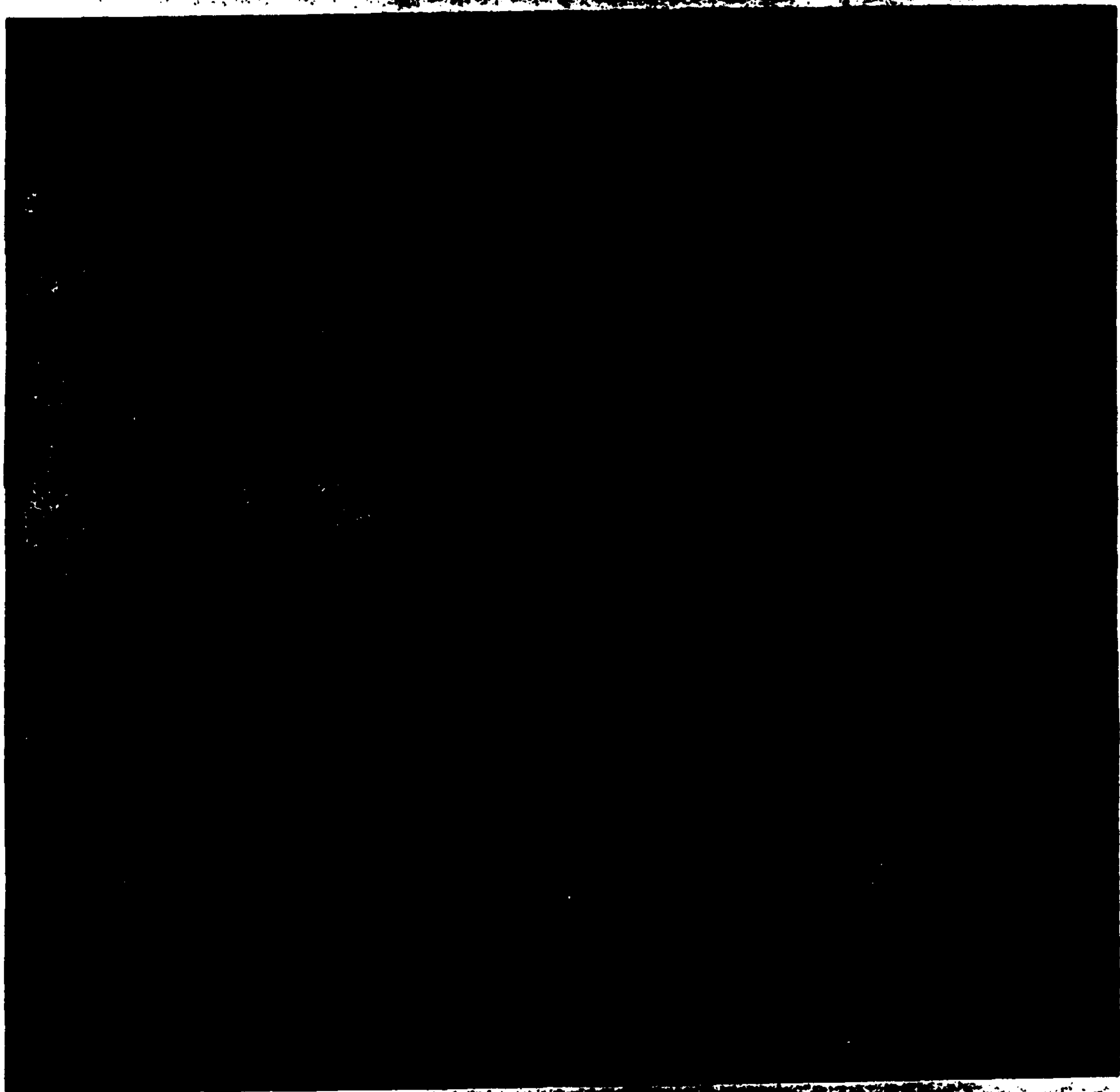
WORST CASE ACCEPTOR
CRUSH TEST SUMMARY

PLATE SPEED	M43 PROPELL	M865 CTG LKL	TOW II MOTOR	M483 A5 FILL	M107 COMP B	DEM CHG COMP B
10 M/S						
20 M/S						
30 M/S		30 NOGO	30 NO GO			
40 M/S	45 BURN		45 BURN	43 NO GO		45 BURN
50 M/S						
60 M/S						
80 M/S	90 BURN	90 BURN	90 BURN	95 EXP	95 NO GO	
100 M/S						
120 M/S						
140 M/S			140 EXP			
160 M/S		170 BURN	170 EXP			
180 M/S						

WORST CASE ACCEPTOR
DOUBLE IMPACT TEST SUMMARY

NOTE: REACTION WAS ALWAYS AT SECOND IMPACT

PLATE SPEED	M43 PROPELL	M865 CTG LKL	TOW II MOTOR	M483 A5 FILL	M107 COMP B	DEM CHG COMP B
10 M/S						15 NO GO
20 M/S						24 EXP
30 M/S			BURN (PAR)	33 NO GO		30 EXP
40 M/S	45 BURN		BURN (PAR)	49 EXP	47 NO GO	45 DET
50 M/S						
60 M/S						
80 M/S						
100 M/S						
120 M/S		125 BURN				
140 M/S			140 EXP			
160 M/S		170 EXP	170 EXP			
180 M/S						



SUMMARY

US ARMY LABORATORY COMMAND

BALLISTIC RESEARCH LABORATORY

BENEFIT: MORE VALUE FROM FUTURE MEDIUM AND LARGE SCALE SYMPATHETIC DETONATION TESTS.

RISK:

* THE IDENTIFIED ITEM(S) MAY BE DIFFICULT TO USE ON TEST RANGES OR VERY EXPENSIVE.

* WE MAY OVERLOOK AN IMPORTANT MECHANISM.

* THE PROCESS OF SELECTING CANDIDATES FOR TESTING MAY BE DEFECTIVE.

* FUZES MAY PLAY A ROLE IN SOME CASES.

HOW MUCH – No Direct User Charges

- USER CONTROLLED NETWORK
- Governed By Joint Service Steering Committee
- Funding
  - Day to Day – Service Funded
  - Ongoing Research – OSD/RCC Support

WHO – All DoD Test and Evaluation (T&E)

- ALL T&E COMMUNITIES
  - Developmental T&E
  - Operational T&E
- ALL SERVICE T&E
  - Air Force
  - Army
  - Navy
  - Marine Corps
- ALL T&E PARTICIPANTS
  - Military
  - Civil Service
  - Sponsored RDT&E Contractors

TECNET Administration
301-826-7501, DSN 326
FAX 301-826-3134
CSD, NAWC-AD, Code CS-44
Patuxent River, Md. 20670

WHY

- Promote Efficiency of T&E within DoD
- Provide a forum for T&E Players
- Support Service/Joint Programs
- Relieve Communications Bottlenecks and Problems
- Increase awareness through Sharing

TECNET

TEST AND EVALUATION COMMUNITY NETWORK

TECNET THE TEST AND EVALUATION COMMUNITY NETWORK

WHAT - A Computer Network Including:

* Full Featured Electronic Mail
  - Multiple addressees/Distribution Lists
  - Carbon Copy/Blind Copy
  - Forwarding/Answering of Messages
  - Return Receipt Capability
  - Password Protected
  - Message Filing System
  - Integarted Facsimile Services
  - Appropriate Security Markings (Secure Version)
* Extensive BULLETIN BOARD Facilities
  - Public (Available to all TECNET users)
  - Private (Communities of Interset/DoD Programs)
  - Restricted (No acknowledgement)
  - Selected ARPANET Bulletin Boards
* Binary FILE REPOSITORY Service
  - Public (Binary or Text)
  - Private (Individualized)
  - Kermit/XMODEM/YMODEM/ZMODEM/Text/FTP
* DATABASE Support
  - Range Commander's Council Bibliography
  - DoD Test and Evaluation Assets
  - Catalog of T&E Data Bases
  - User Directories (TECNET and DDN)
  - Private Data Bases (Specialized Support)
* Specialized USER Services
  - DoD News (Daily)
  - Electronic 'Early Bird' (Daily)
  - Aerospace Daily (Government Users only)
  - Commerce Business Daily (Government only)
  - Teal's Directory (Government users only)
  - Project Reliance Data/TEMP Generator
  - Service Unique Menus
* Extensive HELP Capabilities
  - On line Context Sensitive Help (Brief and Verbose)
  - On line User's Manual
  - On line DDN Manuals

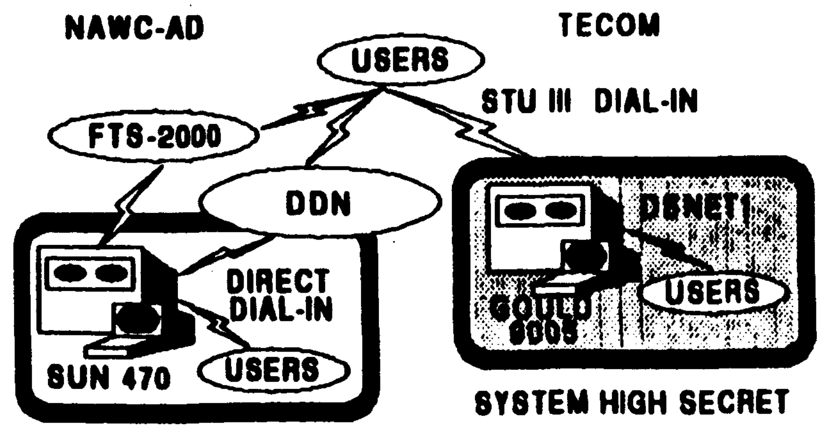
WHEN - 24 Hours/Day, 7 Days/Week

* Maintenance Pre-announced
* Backup Systems Available

WHERE - Multiple Access Methods

(300 to 9600 baud Dial-in/TELNET)

* Defense Data Network (DDN)
  - TELNET (DDN Host to Host Access)
  - Local Dial-in TAC (CONUS/OCONUS)
  - DDN 800 Number Service
* Federal Telephone System for 2000 (FTS-2000)
  - Local "on-net" direct dial-in
  - 800 Number Service
* TECNET System High Secret System
  - 800 Number Access via DSN
  - Commercial 800 Number Service
  - DDN's DSNET1 Access



HOW - User Interface Options

* NOVICE MODE - No Guesswork Menus
* MENU MODE - Simple, Easy to Navigate
* COMMAND MODE - Concise, Approrriate
* EXPERT MODE - Prompts Only
* All modes are interchangeable

TECNET

TECNET SERVICE
NAVAL AIR WARFARE CENTER
AIRCRAFT DIVISION
CS44 BLDG. 1490
PATUXENT RIVER, MD 20670
FAX (301) 826-3134

TECNET USER REQUEST FORM

Please make sure you complete ALL requested information. Failure to provide complete user information will result in processing delays. Please contact "tecadmin" at (301) 826-7501 or AV 326-7501, if you have any questions regarding this form.

Requested Userid:

Rank:

Name:(First, MI, Last)

Organization Name: (Do not abbreviate)

Organization Abbreviation:

Command:

Project:

Complete Mailing Address:
(Organization,Street,Mail Code,City,State,Zip)

Phone (commercial):

Phone (autovon):

FAX Phone (commercial):

FAX Phone (autovon):

Area of Expertise:

Branch of Service:

Status (Govt or Contractor):

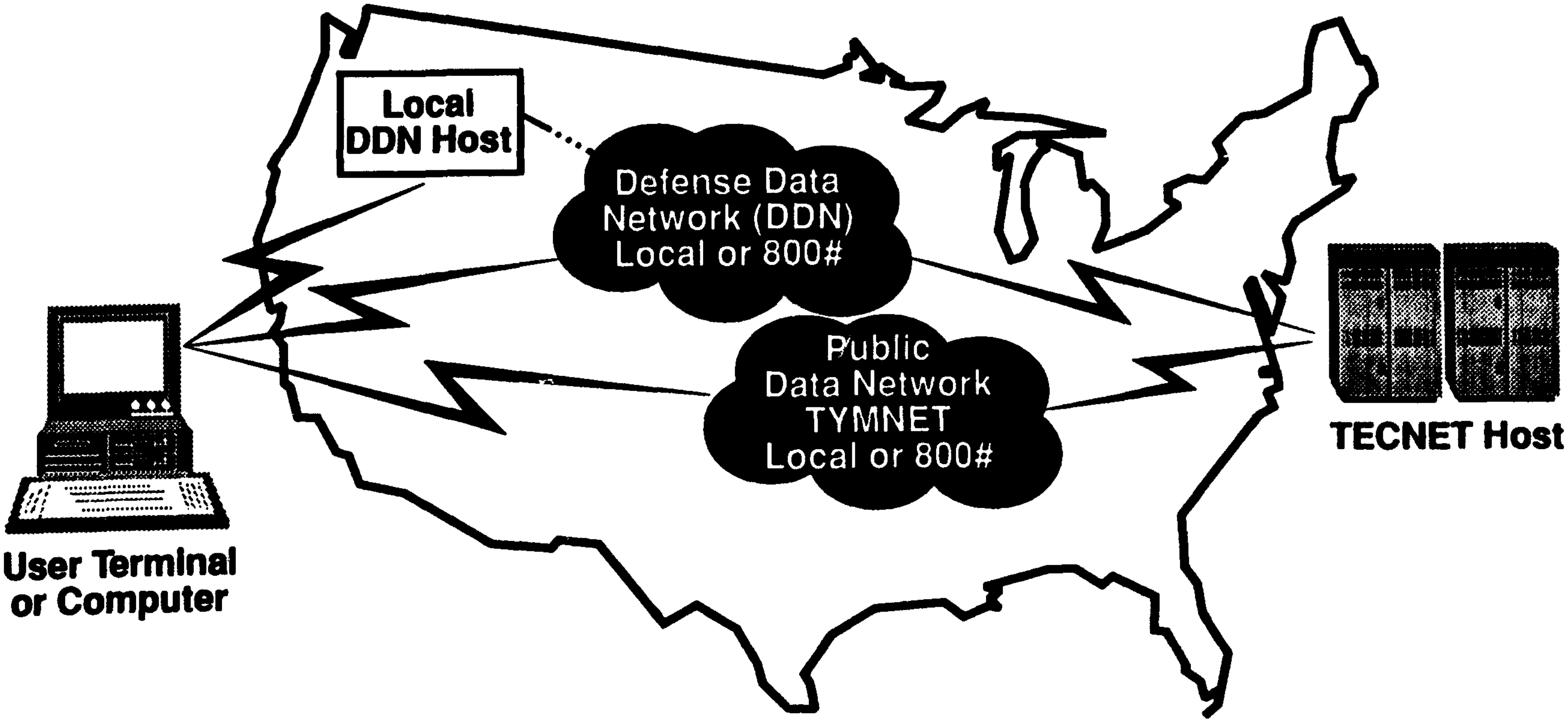
Requestor/Sponsor Userid (Mandatory for Contractors):
Requestor/Sponsor Name:

Arpanet Bulletin Boards (please specify):
Special Boards (please specify):
Do you currently have DDN Access (yes/no)?
(If no, you will be registered for a DDN card)

T E C N E T

What is TECNET?

- TECNET is an Acronym for the Test and Evaluation Community Network
- A Joint Service Network, Operating under the Auspices of the Joint Commander's Group for Test and Evaluation, JCG(T&E)



Nationwide Access

N2005-GA-90-1717-D

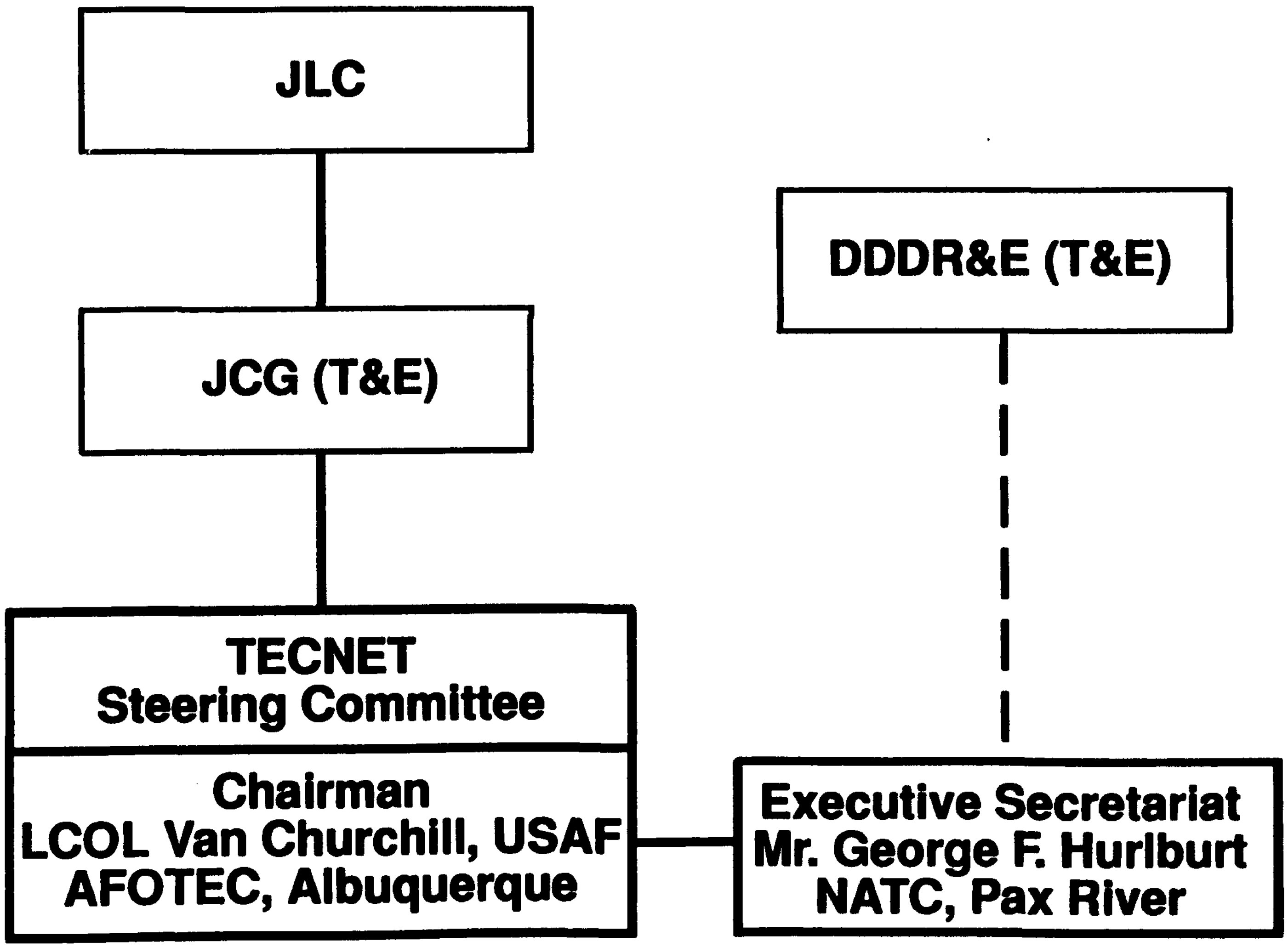
Briefing Outline

- TECNET?
- Background
- Management Structure
- Who Uses TECNET
- User Locations
- Features
- T&E Asset Data Base
- Cost
- Network Uses
- New Features
- 1993 Objective
- Benefits to the PMO
- What's Needed to Hook Up
- How to Sign Up
- Summary

Background

- Initial Contract with Clemson University by DDDR&E(T&E) in 1982 to Network Joint Service Programs
- TECNET Concept Endorsed by Range Commander's Council in 1986
- Tri-Service TECNET Steering Committee was established under OSD in 1987
- JCG(T&E) Chartered the Steering Committee in 1988
- Host Computer Moved to NATC in 1989, Backup Computer at Aberdeen

Management Structure



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Management Structure Steering Committee Members

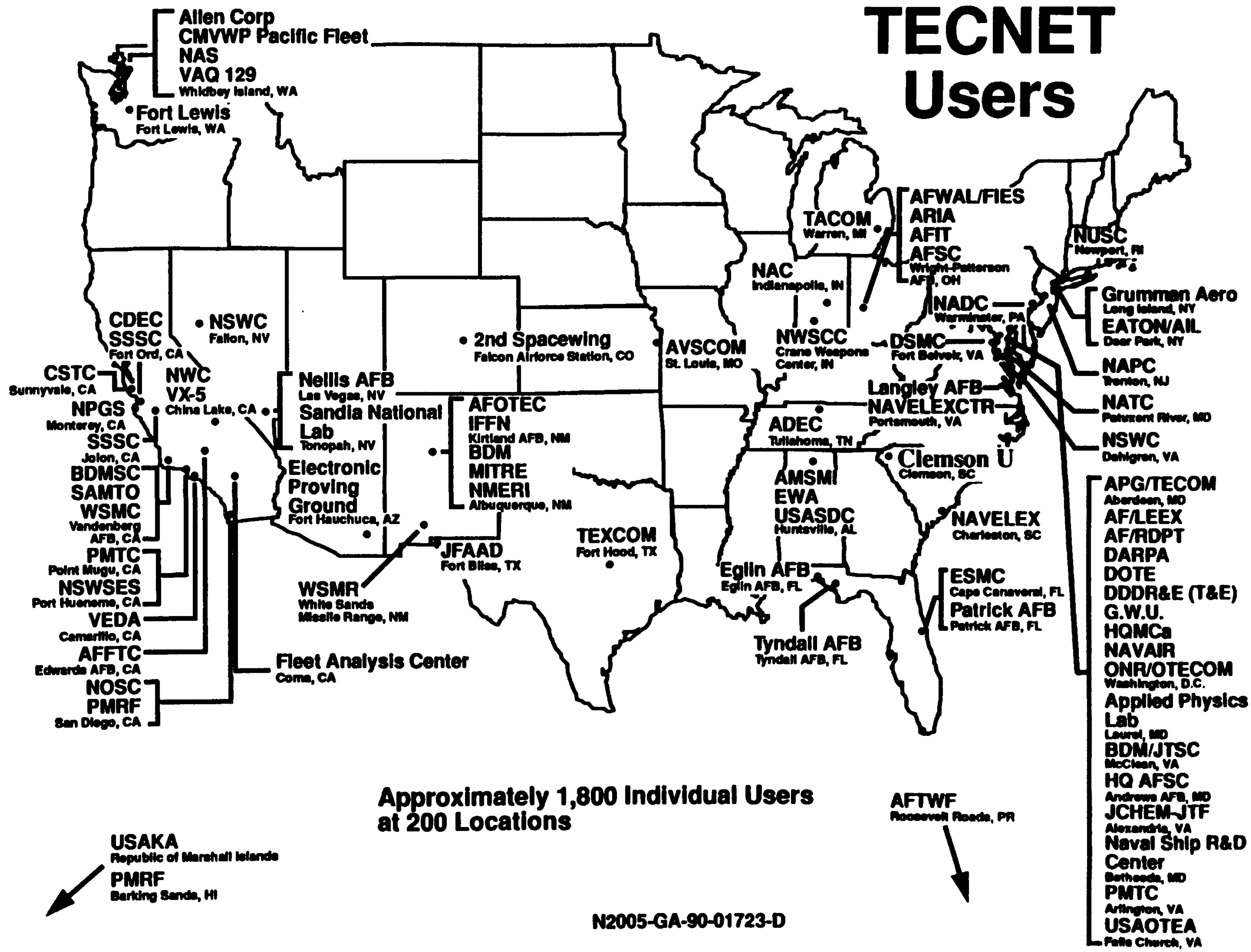
Advisory:	Mr. John Bolino, DDDR&E(T&E)
	Mr. Nick Toomer, DOT&E
Army:	Mr. Ed Stauch, TECOM (DT)
	Mr. Charles Mangum, OPTEC (OT)
Navy:	Mr. Richard G. Turlington, PMTC (DT)
	Mr. James Duff, OPTEVFOR (OT)
Air Force:	LCOL Henry L. Jacocks, Hqts AFSC (DT)
	LCOL Van Churchill, AFOTEC (OT)
RCC:	Dr. Mike Sullivan, OPNAV (Doc Group)
	Mr. David M. Treacy, CSTC (IOG)

N2005-GA-90-1749-D

Who Uses TECNET

- The Test and Evaluation Community
  - Development (DT)
  - Operational (OT)
- Multi-Service Test Investment Review Committee (MSTIRC)
- PEO Staffs
- Program Management Staffs
- Defense Test and Evaluation Professional Institute (DTEPI)

TECNET Users



Approximately 1,800 Individual Users at 200 Locations

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Features

- Bulletin Boards
- DOD T&E Assets Data Base
- MSTIRC Needs and Solutions
- FAX
- Electronic Mail
- Aerospace Daily
- Commerce Business Daily
- News
- Augments LAN's

Features

TECNET Information Menu

1. Mail Services (Mail TECNET Problem Reports To User tecadmin)
2. FAX Services
3. File Transfer/Repository Services
4. DDN Services

5. Special Services
6. Database Systems
7. TECNET Users Directory
8. RCC Applications

9. Setup -- change your session parameters
10. Change your current password
11. Display Current TECNET Attention Message
12. DOD Directives, Information, Manuals, and On-Line Guides

N2005-GA-90-01797-D

Features

1.	Additional Mail Services	
2.	Send Mail	
3.	in	< 0 messages>
4.	old	< 3 messages>
5.	purged	< 1 messages>
6.	out	< 1 messages>
7.	peo	< 16 messages>
8.	*tecnet	< 24 messages>
9.	*newswire	< 13 messages>
0.	*dodnews	< 4 messages>
1.	*contract	< 0 messages>
2.	*bugbox	< 45 messages>
3.	*comments	< 23 messages>
4.	*repository	< 31 messages>
5.	*tecnet-policy	< 3 messages>
6.	*chips	< 3 messages>
7.	*SFTE	< 5 messages>
8.	*whats.new	<154 messages>

Page 1 of 2; 32 total selections.

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Features

TECNET Special Services Menu

The following services are authorized for your account.

1. Administrative Services
2. Aerospace Daily
3. Calendar System
4. System Uptime
5. Area Code/Location/Time

Features

TECNET Data Base Services Menu

The following data base services are authorized for your account.

1. TECNET User's Directory
2. Modify Your Entry to the User's Directory
3. T&E Phones Data Base
4. U.S. Access Telephone Directories
5. DDN TAC Phones Directory
6. RCC Index Retrieval System
7. AFSC Program Manager's Guide & Directory to Test Centers of Expertise
8. DoD T&E Assets Data Base
9. Modify T&E Assets Data Base
10. MSTIRC Services

Network Uses

- EA-6B Program Management
  - Primary Communication Is Email
  - Maintain Electronic Bulletin Boards for EA-6B Community
  - PM Coordinates 30-40 Meetings per Year
  - Software Trouble Reports and Software Enhancement Requests Distributed by Consolidated Lists

EA-6B Program Support Team on TECNET

- OPNAV
- COMMATVAQWINGPAC
- VAQ-129
- NAS Whidbey Island
- NAVAIRHQ Functional Codes
- NATC
- PMTC
- NAC
- APL
- NRL
- VX-5
- COMOPTEVFOR
- NSWC
- ASO
- PG School
- HQMC
- VMAQ-2
- 2nd Marine Air Wing
- Grumman
- PRB
- Sanders
- TI
- United Tech - Norden Systems
- EATON/AIL
- COMPTEK
- Litton
- Teledyne CME
- Singer

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Network Uses

- EA-6B Lessons Learned
  - Program Manager's Office Must Be Dedicated to Daily Use
  - Entire Support Team, Government and Contractors, Needs To Be Online
  - Initial Users Reluctant to Use Due to Lack of Familarity with the System
  - Takes about 2 Months to Get Hooked on Email
  - Users That Don't Like Computers Prefer Using Telephones

Network Uses

- Examples of Network Uses Reported
  - Coordinate T&E Requirements
  - Program Budget Response and Coordination
  - T&E Asset Tracking
  - Transmitting Flight Envelope Clearance Data
  - Report Review and Coordination
  - Scheduling T&E Assets
  - Special Interest Bulletin Boards
  - Elimination of "Phone Tag"
  - Accessing Data Bases
  - Investment Planning and Execution
  - Point Paper Coordination

TECNET VISION

SYSTEMATICALLY MIGRATE EXISTING TECNET RESOURCES TO CREATE A STANDARDS COMPLIANT, MULTI-LEVEL SECURE COMMUNICATIONS AND PROCESSING CAPABILITY WHICH LINKS DEPARTMENT OF DEFENSE TEST AND EVALUATION ENTITIES TO A SHARED, BUT CONTROLLED USER COMMUNITY INFORMATION RESOURCE

STANDARDS COMPLIANT

UNIX -----------------------> POSIX

MILNET DDN *----------> GOSIP

C2 --------------------------> B2

FAX GP III ---------------> ????

MILSPEC ----------------> CALS

DBASE IV ----------------> SQL

1200 BAUD --------------> T-1

CONVENTIONAL ------> RISC

*X.25, TCP\IP, SMTP, FTP, TELNET

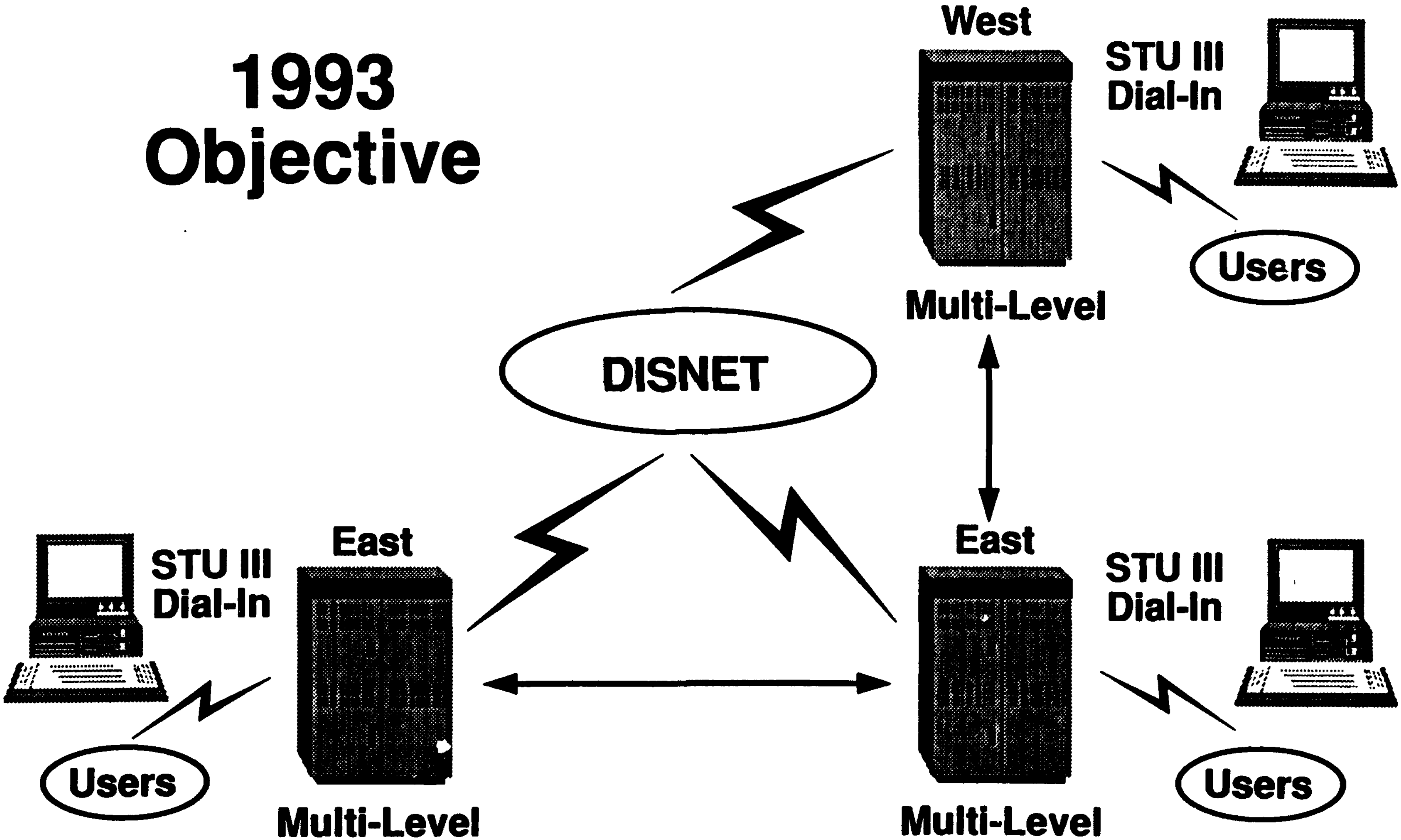
MULTI-LEVEL SECURE

UNCLASSIFIED

CONFIDENTIAL

SECRET

1993 Objective



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TECNET DATA BASE STATUS

ONGOING SUPPORT

- MSTIRC TRMP/NEED/TRC/SOLUTIONS
- RELIANCE BULLETIN BOARDS
- RCC UNIVERSAL DOCUMENTATION/SCHEDULES
- DOD T&E ASSETS (NEW MENU FRONT END)

FORTHCOMING SUPPORT

- DTEPI COURSES/PROFESSIONALS
- OTA DATA BASE(S)
- JLC MANDATED LESSONS LEARNED
- RCC FLIGHT TERMINATION
- RCC REQUIREMENTS CONTRACTS DATA BASE
- DATA BASE OF T&E DATA BASES
- AN/ALR-57 DEFICIENCY TRACKING
- DATA DRIVEN TEMP TEMPLATE

New Features

- FAX Capability - Feb 1991
- New Sun 470 Host Computer - Jul 1991
- Secure Communications Up to Secret - Jul 1991
- dBASE IV - 1992
- Inter-Range Documentation (IRDOC) - 1992
- Multi-level Secure - 1993

Benefits to the PMO

- User Friendly
- Direct Electronic Information Connection with the DOD Acquisition Community
- No Direct Program Costs
- Adaptable to Meet Specific Needs
- Growth Available to Meet Increased Needs
- Designed to Meet Changing Needs of Users

Cost

- DDDR&E(T&E) Is Providing R&D Development Funds (30%)
- Services Funding O&M Funds (70%)
- FY91 Budget Approximately $1M
- FY92 Budget Approximately $1.2M

What's Needed to Hook Up

- Personal Computer (PC)
- Modem - 300 to 2,400 Baud with Software
- Telephone Connection into DDN or TYMNET

Summary

- TECNET Is:
  - A Here-and-Now Electronic Network
    - Built on a Sound Approach
    - State-of-the-Art and Staying Current
    - User Friendly
    - Reliable
    - Flexible
    - Secure
    - Augments LAN's
  - An Effective Program Management Tool

NSWC
Naval Surface Warfare Center
DAHLGREN DIVISION

STATUS OF MIL-STD-1751A

BRYAN BAUDLER
CODE R16
NAVAL SURFACE WARFARE CENTER
WHITE OAK

15 APRIL 1993

MIL-STD-1751A STATUS

WHAT IS IT?

- o TRI-SERVICE DOCUMENT COVERING STANDARDIZATION OF QUALIFICATION REQUIREMENTS AND TESTS FOR ALL ENERGETIC MATERIALS.

- o WILL REPLACE:

  -OD 44811 (NAVY)
  -ADA-086259 (ARMY)
  -MIL-STD-1751 (AIR FORCE)

- o IMPLEMENTATION DOCUMENT OF NATO STANDARDIZATION AGREEMENT (STANAG) 4170 - ACCORD REACHED TO USE UNIFORM TEST PROCEDURES FOR QUALIFICATION THROUGHOUT NATO

NSWC Naval Surface Warfare Center DAHLGREN DIVISION

MIL-STD-1751A STATUS

BACKGROUND

- EFFORT STARTED IN 1989 UNDER THE SPONSORSHIP OF JOCG TO IMPLEMENT NATO AGREEMENT (STANAG 4170)

- MIL-STD-1751 (AIR FORCE QUALIFICATION PROCEDURES) WAS SELECTED FOR REVISION - WOULD INCLUDE ARMY AND NAVY REQUIREMENTS

- EACH SERVICE AGREED TO PROVIDE FUNDING AND PERSONNEL TO SUPPORT THE EFFORT - NAVY AGREED TO TAKE LEAD

NSWC
Naval Surface Warfare Center
DAHLGREN DIVISION

MIL-STD-1751A STATUS

OBJECTIVES

- o STANDARDIZE EXPLOSIVE QUALIFICATION REQUIREMENTS AND TEST PROCEDURES AMONG THE THREE SERVICES
- o UPDATE AND INCORPORATE NEW TEST PROCEDURES
- o IMPLEMENT NATO STANAG 4170
- o REDUCE COSTS ASSOCIATED WITH QUALIFICATION
- o SIMPLIFY JOINT SERVICE DEVELOPMENT EFFORTS

MIL-STD-1751A STATUS

PARTICIPANTS

AIR FORCE
EGLIN AFB, EDWARD AFB

ARMY
MICOM (HUNTSVILLE) AND ARDEC (PICATINNY)

DOD EXPLOSIVES SAFETY BOARD

NAVY
NAWC (CHINA LAKE), NSWC (CRANE, INDIAN HEAD, YORKTOWN, AND WHITE OAK), NAVSEA

MIL-STD-1751A STATUS

TECHNICAL APPROACH

- SPECIFIC STIMULI TO BE EVALUATED IDENTIFIED FOR DIFFERENT CLASSES OF ENERGETIC MATERIALS

MAIN CHARGE EXPLOSIVES
BOOSTER EXPLOSIVES
PRIMARY EXPLOSIVES
LIQUID PROPELLANTS
SOLID PROPELLANTS
PYROTECHNICS

- SOME VARIATIONS IN TEST APPARATUS AND PROCEDURES WILL BE ALLOWED FOR SPECIFIC STIMULI AS LONG AS RESULTS ARE COMPARED TO STANDARD MATERIALS

- INCORPORATE DOT HAZARD CLASSIFICATION REQUIREMENTS

- EACH SERVICE WOULD STILL QUALIFY MATERIALS THROUGH THEIR DESIGNATED LEAD ACTIVITIES

MIL-STD-1751A

RELATIONSHIP TO THE ACQUISITION CYCLE

HIGH EXPLOSIVES

ARE DEVELOPED FOR GENERAL APPLICATIONS SUCH AS BLAST, UNDERWATER PERFORMANCE, METAL ACCELERATING CAPABILITY, BOOSTER OR PRIMARY

THEY ARE QUALIFIED PRIOR TO TESTING IN MUNITIONS APPLICATIONS

PROPELLANTS

ARE DEVELOPED FOR SPECIFIC SYSTEMS AND ARE GENERALLY TAILORED RIGHT UP UNTIL QUALIFICATION TESTING OF THE PROPULSION SYSTEM

QUALIFICATION OF THE PROPELLANT WILL COINCIDE WITH QUALIFICATION OF THE ITEM

NSWC
Naval Surface Warfare Center
DAHLGREN DIVISION

MIL-STD-1751A STATUS

TEST DESCRIPTION

- o PURPOSE
- o SAMPLE PREPARATION
- o TEST SETUP
- o ENVIRONMENTAL REQUIREMENTS
- o TEST PROCEDURE
- o DATA OBTAINED ON "KNOWN" MATERIALS
- o STANDARD DATA SHEET FOR REPORTING OF RESULTS
- o REFERENCES

NSWC Naval Surface Warfare Center DAHLGREN DIVISION

MIL-STD-1751A STATUS

REQUIRED TESTS - HIGH EXPLOSIVES

TEST	PRIMARY	BOOSTER	MAIN CHARGE
IMPACT SENSITIVITY	X	X	X
FRICTION SENSITIVITY	X	X	X
ESD SENSITIVITY - SMALL SCALE	X	X	X
ESD SENSITIVITY - LARGE SCALE	-	-	X
SHOCK SENSITIVITY	-	X	X
VACUUM THERMAL STABILITY/CRT	X	X	X
CRITICAL DIAMETER	-	X	X
SELF HEATING (DSC/DTA)	X	X	X
CAP TEST	-	X	X
THERMAL STABILITY (75°C TEST)	-	X	X
DETONATION VELOCITY	-	X	X
TOXICITY	X	X	X

Naval Surface Warfare Center
DAHLGREN DIVISION

MIL-STD-1751A STATUS

REQUIRED TESTS - PROPELLANTS

TEST	SOLID	LIQUID
IMPACT SENSITIVITY	X	X
FRICTION SENSITIVITY	X	X
ESD SENSITIVITY - SMALL SCALE	X	X
ESD SENSITIVITY - LARGE SCALE	X	X
SHOCK SENSITIVITY	X	X
VACUUM THERMAL STABILITY/CRT	X	-
MIN PRESSURE FOR VAPOR IGNITION	-	X
SELF HEATING (DSC/DTA)	X	X
CAP TEST	-	X
THERMAL STABILITY (75°C TEST)	X	X
THIN FILM PROPAGATION	-	X
FLASH POINT - LIQUID EXPLOSIVES	-	X
TOXICITY	X	X

NSWC
Naval Surface Warfare Center
DAHLGREN DIVISION

MIL-STD-1751A STATUS

REQUIRED TESTS - PYROTECHNICS

TEST	PYROTECHNICS
IMPACT SENSITIVITY	X
FRICTION SENSITIVITY	X
ESD SENSITIVITY - SMALL SCALE	X
SELF HEATING (DSC/DTA)	X
CAP TEST	X
VACUUM THERMAL STABILITY/CRT	X
THERMAL STABILITY (75°C TEST)	X
TOXICITY	X

NSWC Naval Surface Warfare Center DAHLGREN DIVISION

MIL-STD-1751A STATUS

STATUS

- o 1ST DRAFT OF MIL-STD-1751A DISTRIBUTED IN DECEMBER 1992
- o DOCUMENT DISTRIBUTED TO TRI-SERVICE AGENCIES ASSOCIATED WITH ENERGETIC MATERIAL QUALIFICATION AND EVALUATION
- o COMMENTS RECEIVED ARE BEING INCORPORATED IN A FINAL DRAFT TO BE DISTRIBUTED BY 1 AUGUST 1993
- o FINAL PUBLICATION PLANNED BY 1 JANUARY 1994

PROGRAM OVERVIEW AND RD&T PLANNING
FOR

THE JOINT U.S./ROK
RESEARCH, DEVELOPMENT, AND TESTING PROGRAM
FOR NEW UNDERGROUND AMMUNITION
STORAGE TECHNOLOGIES

PRESENTED TO:

THE 5TH TRI-SERVICE SYMPOSIUM
ON EXPLOSIVES TESTING

SILVER SPRING, MD
15 APRIL 1993

PRESENTED BY:
MR. RICHARD H. CASHIN
OFFICE OF THE U.S. PROGRAM MANAGER

NARRATIVE

COVER - 1

GOOD AFTERNOON. I AM RICHARD H. CASHIN FROM THE U.S. ARMY TECHNICAL CENTER FOR EXPLOSIVES SAFETY IN SAVANNA, ILLINOIS. I AM IN THE OFFICE OF THE U.S. PROGRAM MANAGER FOR THE JOINT U.S./REPUBLIC OF KOREA RESEARCH, DEVELOPMENT, AND TEST PROGRAM TO DEVELOP NEW UNDERGROUND AMMUNITION STORAGE TECHNOLOGIES.

I WILL PRESENT TO YOU TODAY A BRIEF OVERVIEW OF THE PROGRAM AND THE ON-GOING AND PLANNED TEST ACTIVITIES. I WILL BE GLAD TO ANSWER YOUR QUESTIONS AT THE CONCLUSION OF THIS PRESENTATION. SHOULD YOU HAVE SPECIFIC QUESTIONS ON THE TEST PLANNING, WE WILL PRESENT THEM TO MR. KIM DAVIS THE U.S. TECHNICAL PROGRAM MANAGER.

- PROGRAM MANAGERS

  ROK COLONEL JIN, SOO-JUN
  EXPLOSIVES SAFETY MANAGEMENT BOARD, MND

  U.S. MR. GARY W. ABRISZ
  U.S. ARMY TECHNICAL CENTER FOR EXPLOSIVES SAFETY

- TECHNICAL MANAGERS

  ROK DR. SONG, SO-YOUNG
  AGENCY FOR DEFENSE DEVELOPMENT

  U.S. MR. L. KIM DAVIS
  U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION

VUGRAPH 2

THE PROGRAM MANAGERS AND TECHNICAL PROGRAM MANAGERS ARE SHOWN ON THIS CHART.

THE U.S. PROGRAM MANAGER IS MR. GARY W. ABRISZ, ASSOCIATE DIRECTOR OF THE U.S. ARMY TECHNICAL CENTER FOR EXPLOSIVES SAFETY. HIS COUNTERPART, THE KOREAN PROGRAM MANAGER IS REPUBLIC OF KOREA ARMY COLONEL JIN, SOO-JUN. MR. L. KIM DAVIS, U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, IS THE U.S. PROGRAM'S TECHNICAL MANAGER. HIS KOREAN COUNTERPART IS DR. SONG, SO-YOUNG THE AGENCY FOR DEFENSE DEVELOPMENT IN TAEJON, KOREA.

PRESENTATION OUTLINE

- INTRODUCTION
- GOAL/OBJECTIVE
- ISSUE
- BACKGROUND
- RESPONSIBLE ORGANIZATIONS
- PLAN
- EXPECTED RESULTS
- CONCLUSION

VUGRAPH 3

THIS IS THE OUTLINE FOR MY PRESENTATION.

GOAL

- IDENTIFY, TEST, EVALUATE, AND DEMONSTRATE NEW UNDERGROUND AMMUNITION STORAGE DESIGN CONCEPTS

OBJECTIVE

- DESIGN TO REDUCE OR CONTROL EXTERNAL BLAST AND DEBRIS EFFECTS FROM AN ACCIDENTAL EXPLOSION UNDERGROUND

VUGRAPH 4

THE PROGRAM GOAL AND MAIN OBJECTIVE ARE STATED HERE. THE PROGRAM IS ESTABLISHED TO END WITH APPROVED NEW DESIGN CONCEPTS FOR APPLICATION WITHIN THE REPUBLIC OF KOREA WHICH SHOULD HAVE APPLICATIONS WORLDWIDE.

OVER THE LAST DECADE, A NUMBER OF EXPLOSIVE TESTS HAVE BEEN CONDUCTED TO INVESTIGATE THE HAZARDOUS EFFECTS THAT MAY BE PRODUCED BY ACCIDENTAL EXPLOSIONS IN UNDERGROUND MAGAZINES. THESE EFFECTS INCLUDE AIRBLAST, DEBRIS THROW, GROUND SHOCK, AND THE PROPAGATION OF AN EXPLOSION TO ADJACENT STORES OF AMMUNITION. THE TESTS PROVIDE EXPERIMENTAL DATA REQUIRED TO REFINE THE CURRENT DEPARTMENT OF DEFENSE (OR NORTH ATLANTIC TREATY ORGANIZATION) SAFETY STANDARDS, AND/OR TO EVALUATE NEW DESIGN FEATURES FOR UNDERGROUND MAGAZINES.

NEW CONCEPTS FOR UNDERGROUND MAGAZINES ARE PRESENTLY BEING EVALUATED, EITHER TO PROVIDE NEW STORAGE CAPABILITIES, OR TO DRASTICALLY REDUCE THE PRESENT HAZARD RANGES FOR UNDERGROUND AMMUNITION STORAGE. IN SPITE OF THE TREMENDOUS ADVANCES IN OUR ABILITY TO MATHEMATICALLY SIMULATE THE COMPLEXITIES OF MAGAZINE EXPLOSIONS USING COMPUTER MODELS, SMALL-SCALE EXPLOSIVE TESTS CONTINUE TO BE AN INVALUABLE SOURCE OF DATA AND INSIGHTS. THE JOINT U.S./REPUBLIC OF KOREA RESEARCH AND DEVELOPMENT PROGRAM FOR NEW UNDERGROUND AMMUNITION STORAGE TECHNOLOGIES, WILL INVOLVE EXTENSIVE SMALL-SCALE AND

VUGRAPH 4 (CONT)

INTERMEDIATE-SCALE TESTING TO INVESTIGATE, EVALUATE, AND DOWN-SELECT PROMISING DESIGN FEATURES THAT SHOULD ENABLE US TO GREATLY REDUCE THE EXTERNAL HAZARDS FROM AN UNDERGROUND MAGAZINE. OUR DIRECT EMPHASIS HAS BEEN ON OUR STORAGE IN THE REPUBLIC OF KOREA.

ISSUE

- U.S./ROK AGREEMENTS REQUIRE APPLICATION OF THE U.S. DOD AMMUNITION AND EXPLOSIVES SAFETY STANDARDS

- SERIOUS QUANTITY DISTANCE (QD) VIOLATIONS EXIST IN ROK

- PERMIT A REALISTIC USE OF U.S./ROK TECHNICAL CAPABILITIES TO REDUCE QD REQUIREMENTS IN THE ROK AND THE U.S.

VUGRAPH 5

THE ISSUE THE DEPARTMENT OF DEFENSE WAS FACING IN KOREA IN THE MID 1980s AND CONTINUES TO RECOGNIZE, IS WHAT HAS GENERATED THIS OFFICE OF THE SECRETARY OF DEFENSE-DIRECTED AND ARMY MANAGED PROGRAM. THE STORAGE OF U.S. DEPARTMENT OF DEFENSE AMMUNITION IN KOREA RELATES TO APPLICATION OF U.S. EXPLOSIVES SAFETY STANDARDS.

THE SITUATION IS CURRENTLY THAT THE STANDARDS CAN NOT BE ACCOMMODATED TO THE FULL EXTENT AND MANY VIOLATIONS AND EXPOSURES RESULT.

THIS RESEARCH AND DEVELOPMENT EFFORT AS STATED IS TO DETERMINE THE USE OF NEW TECHNICAL APPLICATIONS TO REDUCE QUANTITY DISTANCE REQUIREMENTS.

THE MEMORANDUM OF AGREEMENT AND THE ASSOCIATED STATEMENT OF WORK ARE DIRECTED TOWARD THIS ISSUE. THEY ARE INTENDED TO DESIGN CONCEPTS TO ELIMINATE THE EXISTING SERIOUS EXPLOSIVES SAFETY VIOLATIONS IN THE REPUBLIC OF KOREA AS WELL AS THROUGHOUT THE DEPARTMENT OF DEFENSE STORAGE COMPLEX.

BACKGROUND

SEP 1987 - DDESB EXPLOSIVES SAFETY SURVEY IDENTIFIED VIOLATIONS AND CONCERNS

AUG 1988 - U.S. DOD AND ROK MND ESTABLISHED A JOINT TECHNICAL WORKING GROUP

MAR 1989 - SEVEN PROPOSED STORAGE CONCEPTS WERE EVALUATED

VUGRAPH 6

WITH THAT AS THE ISSUE, I WOULD LIKE TO NOW QUICKLY COVER THE BACKGROUND RELATIVE TO THE PROGRAM DEVELOPMENT. BEGINNING IN THE 1985 AND 1987 TIME PERIOD WHEN THE VIOLATIONS IN KOREA WERE FIRST DOCUMENTED BY THE DEPARTMENT OF DEFENSE EXPLOSIVES SAFETY BOARD, OUR DEPARTMENT OF DEFENSE AND REPUBLIC OF KOREA MINISTRY OF NATIONAL DEFENSE DIRECTED ESTABLISHMENT OF A TECHNICAL WORKING GROUP TO RESOLVE THE ISSUE.

SEVERAL PROPOSALS WERE GENERATED AND WERE EVALUATED BY THE GROUP MADE UP OF REPRESENTATIVES OF DEPARTMENT OF DEFENSE EXPLOSIVES SAFETY BOARD, U.S. ARMY, U.S. NAVY, U.S. AIR FORCE, AND REPUBLIC OF KOREA MINISTRY OF NATIONAL DEFENSE.

THE UNDERGROUND STORAGE CONCEPT PRESENTED BY WATERWAYS EXPERIMENT STATION AT THAT TIME WAS SELECTED AMONG THE VARIOUS SERVICE CONCEPTS PRESENTED. THE MOUNTAINOUS TERRAIN AND GRANITE ROCK GEOLOGY IN KOREA ADAPTS WELL TO THIS UNDERGROUND CONCEPT.

BACKGROUND

JUL 1989 - U.S./ROK STATEMENT OF INTENT

FEB 1990 - UNDERGROUND STORAGE CONCEPT SELECTED

MAR 1990 - A JOINT R&D PLAN RESULTED IN A DRAFT MOA

VUGRAPH 7

THE U.S./REPUBLIC OF KOREA SIGNED A STATEMENT OF INTENT TO ENTER INTO AN AGREEMENT IN JULY 1989.

A DRAFT MEMORANDUM OF AGREEMENT WAS DEVELOPED IN MARCH OF 1990.

BACKGROUND

APR 1990 - CANDIDATE FOR NUNN AMENDMENT COOPERATIVE R&D PROGRAM FUNDS

MAY 1990 - DRAFT MOA TO HQDA AND OSD FOR STAFFING

- PROJECT IDENTIFIED FOR HQDA FUNDING FY 94 AND FY 95

NOV 1990 - CERTIFIED BY OUSD(A) (NUNN $)

VUGRAPH 8

IN 1990 ALSO, HEADQUARTERS, DEPARTMENT OF THE ARMY IDENTIFIED PROGRAM FUNDING FOR OUTYEARS. THE PROGRAM WAS CERTIFIED BY OFFICE OF THE UNDER SECRETARY OF DEFENSE FOR ACQUISITION AS AN APPROVED CANDIDATE FOR THE U.S. CONGRESSIONAL NUNN AMENDMENT COOPERATIVE RESEARCH AND DEVELOPMENT PROGRAM FUNDING IN NOVEMBER OF THAT YEAR. A TOTAL OF $9.5M WAS PROGRAMMED. THE REPUBLIC OF KOREA HAS PROGRAMMED A SIMILAR AMOUNT.

BACKGROUND

JAN 1991 - OUSD(A) AUTHORITY TO NEGOTIATE AND CONCLUDE MOA

APR 1991 - MOA NEGOTIATIONS AND AGREEMENT

JUL-AUG 1991 - MOA SIGNED

AUG 1991 - NUNN FUNDS RELEASE - R&D COMMENCES

VUGRAPH 9

A WHOLE SERIES OF NEGOTIATIONS TOOK PLACE AND IN 1991 A MEMORANDUM OF AGREEMENT AND STATEMENT OF WORK RESULTED. THE FUNDING WAS PROVIDED AND OUR RESEARCH AND DEVELOPMENT EFFORTS GOT UNDERWAY.

U.S. TECHNICAL ADVISORY GROUP (TAG)

PURPOSE

ADVISE THE PROGRAM MANAGERS (PMs) AND TECHNICAL MANAGERS ON THE NEW UNDERGROUND AMMUNITION STORAGE TECHNOLOGIES (UAST) PROGRAM ACTIVITIES AND CONCEPTS

VUGRAPH 10

BOTH THE U.S. AND REPUBLIC OF KOREA HAVE ESTABLISHED TECHNICAL ADVISORY GROUPS. WE AGREED TO DO THIS IN OUR MEMORANDUM OF AGREEMENT NEGOTIATIONS. THIS CHART SHOWS OUR TECHNICAL ADVISORY GROUP PURPOSE. A CHARTER HAS BEEN DEVELOPED AND INCORPORATED INTO THE PROGRAM DOCUMENTS.

THE U.S. HAS HAD THREE MEETINGS AND THE REPUBLIC OF KOREA HAS HAD ONE. REPUBLIC OF KOREA REPRESENTATIVES ATTENDED THE FIRST U.S. MEETING AT WATERWAYS EXPERIMENT STATION AND U.S. REPRESENTATIVES ATTENDED THE FIRST REPUBLIC OF KOREA MEETING AT THE AGENCY FOR DEFENSE DEVELOPMENT IN TAEJON, REPUBLIC OF KOREA IN 1992. OUR NEXT U.S. MEETING IS SCHEDULED FOR JUNE 1993 AT SOCORRO, NEW MEXICO.

U.S. TAG MEMBERSHIP

ORGANIZATION	NAME
DDESB SECRETARIAT	DR. CHESTER E. CANADA
USAF:	
AFSA	MR. PAUL D. PRICE, P.E.
U.S. ARMY:	
CEMRO	MR. WILLIAM GAUBE
CEHND	MR. PAUL LAHOUD
ARL	MR. ONA R. LYMAN
AMC DCS AMMO	MR. ROBERT J. FAHY
U.S. NAVY:	
NSWC	MR. MICHAEL M. SWISDAK
NCEL	MR. JAMES E. TANCRETO
KOREA:	
U.S., USFK J4	MRS. BARBARA J. OVERTON

VUGRAPH 11

YOU SEE MANY FAMILIAR NAMES ON THIS CHART.

THIS MEMBERSHIP REPRESENTS MUCH OF THE EXPLOSION EFFECTS EXPERTISE WITHIN THE U.S. DEPARTMENT OF DEFENSE. THE U.S. ARMY MATERIEL COMMAND, DEPUTY CHIEF OF STAFF FOR AMMUNITION, AND U.S. FORCES, KOREA, J4, REPRESENT THE LOGISTICS INPUT AND THE USER REQUIREMENT CONSIDERATIONS IN THIS CONCEPT DEVELOPMENT. AS A MEMBER OF THE DEPARTMENT OF DEFENSE EXPLOSIVES SAFETY BOARD SECRETARIAT, DR. CANADA PROVIDES THE CHAIRMANSHIP IN SUPPORT OF THE PROGRAM AND TECHNICAL MANAGERS.

THE REPUBLIC OF KOREA HAS AN EQUALLY QUALIFIED AND AN IMPRESSIVE GROUP OF EXPERTS TO REVIEW THEIR ACTIVITIES AND COORDINATE WITH THIS U.S. GROUP OF EXPERTS. WE HAVE BEEN VERY MUCH IMPRESSED BY THEIR ACTIVITIES AND RESULTS.

PLAN

- FIVE PHASE STATEMENT OF WORK:
  - CY 91 - PHASE 1: R&D PLANNING AND PREPARATION
  - CY 92 - PHASE 2: SMALL-SCALE TEST PROGRAM
  - CY 93 - PHASE 3: INTERMEDIATE-SCALE INVESTIGATIONS
  - CY 94 - PHASE 4: VALIDATION TESTS
  - CY 95 - PHASE 5: FINAL CONCEPT DESIGNS (AND PORTION OF CY 96)

VUGRAPH 12

THIS CHART SIMPLY SHOWS THAT THE PROGRAM HAS BEEN PLANNED OUT OVER A FIVE PHASE PERIOD. THE STATEMENT OF WORK REFLECTS THIS. THE FACT THAT WE STARTED WITH FUNDING ORIGINALLY INTENDED FOR 1990 IN EARLY SEPTEMBER 1991, MEANS THAT THE FIVE PHASE PROGRAM WILL NOW EXTEND INTO 1996. THE ORGANIZATION OF THE PROGRAM RELATES TO THE INITIAL PLANNING AND PREPARATION THROUGH SMALL-SCALE TESTING INTO INTERMEDIATE TESTS AND THEN MUCH LARGER VALIDATION TESTS. THESE WILL PROBABLY OCCUR IN PLACES LIKE SOCORRO, NEW MEXICO AND CHINA LAKE, CALIFORNIA. ALL OF THE PHASES ARE FOR THE PURPOSE OF CULMINATING IN FINAL CONCEPT DESIGNS THAT CAN BE APPROVED BY BOTH THE REPUBLIC OF KOREA EXPLOSIVES SAFETY MANAGEMENT BOARD AND THE U.S. DEPARTMENT OF DEFENSE EXPLOSIVES SAFETY BOARD. I WILL SPEAK IN GENERAL TO THE RESEARCH AND DEVELOPMENT PLANNING AND TESTING WITH THE FOLLOWING CHARTS.

PHASE 1. R&D PLANNING AND PREPARATION

- DESIGNATE TECHNICAL PROGRAM MANAGERS AND ORGANIZE RESEARCH TEAMS
- ESTABLISH TECHNICAL ADVISORY GROUP
- LITERATURE SEARCH
- IDENTIFY AND SELECT COMPUTER CODES FOR ANALYSIS OF MAGAZINE DESIGNS (E.G., SPIDS, SHARC, AB-HULL, BLASTIN)
- OBTAIN GAGES AND OTHER TEST EQUIPMENT
- IDENTIFY PROMISING TECHNIQUES FOR REDUCTION OF PRESSURE/IMPULSE FROM EXPLOSIONS IN UNDERGROUND MAGAZINES: DESIGN SMALL-SCALE TEST PROGRAM

VUGRAPH 13

PHASE 1 HAS BEEN COMPLETED ACCOMPLISHING THE ACTIONS ON THIS CHART. I HAVE MENTIONED THE PROGRAM MANAGERS AND THE U.S. AND REPUBLIC OF KOREA TECHNICAL PROGRAM MANAGERS WERE ESTABLISHED TO PLAN THIS COORDINATED REPUBLIC OF KOREA/U.S. RESEARCH AND DEVELOPMENT PROGRAM. THE LEAD LABS IN REPUBLIC OF KOREA (AGENCY FOR DEFENSE DEVELOPMENT) AND U.S. (WATERWAYS EXPERIMENT STATION) ARE RESPONSIBLE FOR ACCOMPLISHING THESE TECHNICAL ACTIVITIES.

WE RECRUITED MEMBERS FROM ORGANIZATIONS WITH EXPERTISE RELATED TO RESEARCH AND DEVELOPMENT OBJECTIVES, TO ADVISE ON RESEARCH AND DEVELOPMENT PROGRAM PROGRESS AS A TECHNICAL ADVISORY GROUP, AS I DISCUSSED PREVIOUSLY.

WE HAVE ASSEMBLED PERTINENT DOCUMENTS THROUGH A LITERATURE SEARCH. WE CONTINUE TO ANALYZE EXISTING RESEARCH AND DEVELOPMENT INFORMATION TO IDENTIFY PRESENT TECHNOLOGY FOR PREDICTION AND CONTROL OF EXPLOSION HAZARDS FOR UNDERGROUND MAGAZINES.

AREAS OF EMPHASIS IN THE SEARCH CATEGORIES HAVE BEEN:

- AIRBLAST PRESSURE/IMPULSE EFFECTS INTERNALLY, AT THE EXIT, AND EXTERNAL TO THE PORTAL.

VUGRAPH 13 (CONT)

- WE ARE CONSIDERING CHAMBER SEPARATION (WITH RESPECT TO SYMPATHETIC DETONATION FROM AIRBLAST, GROUND SHOCK, AND SPALLING OF ADJACENT WALL).

WE ARE LOOKING AT INFORMATION AND DATA ON:

- BUFFER/BAFFLED STORAGE SYSTEMS (TO REDUCE SYMPATHETIC DETONATIONS).
- GROUND SHOCK HAZARDS (FREE FIELD).
- EJECTA DEBRIS HAZARDS AND DEBRIS TRANSPORT MECHANICS (IN TUNNEL AND EXTERNAL).
- AND ALSO IDENTIFYING PERTINENT DATA FROM SHOCK TUBES AND LARGE GUN TESTS.

WATERWAYS EXPERIMENT STATION AND THE AGENCY FOR DEFENSE DEVELOPMENT CONTINUE TO:

- EVALUATE CODE CAPABILITIES AND LIMITATIONS.
- AND VERIFY CODES AGAINST EXPERIMENTAL DATA.
- EVALUATE DATA ON EFFECTS OF LOADING DENSITY (BASED ON CHAMBER VOLUME AND TOTAL VOLUME).

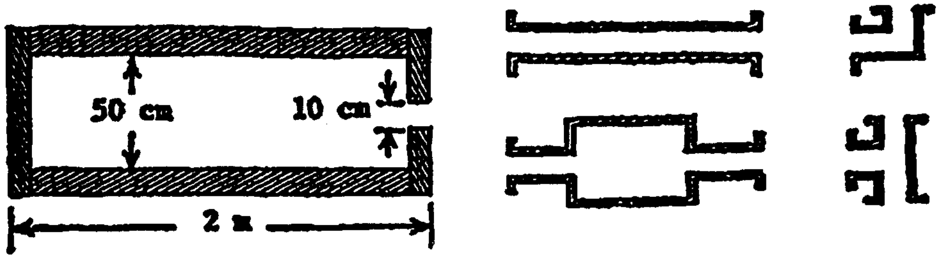
PHASE 2 SMALL-SCALE TEST PROGRAM

- CONSTRUCTION OF SMALL-SCALE TEST FACILITIES (U.S. AND ROK)
- CONDUCT SMALL-SCALE EXPLOSIVE TEST PROGRAM
- COMPUTER MODEL STUDIES OF CHAMBER/TUNNEL DESIGN PERFORMANCE
- EVALUATE RESULTS OF SMALL-SCALE TESTS AND COMPUTER MODEL STUDIES
- SELECT BEST DESIGN FEATURES FOR FURTHER STUDY

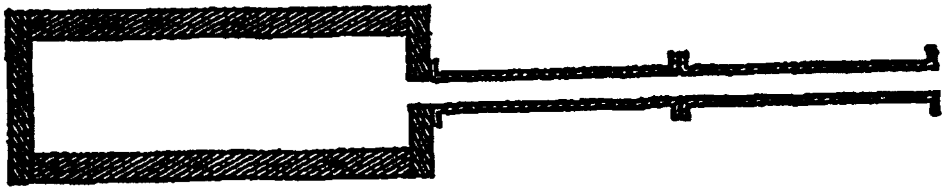
PHASE 2 NARRATIVE

VUGRAPH 14

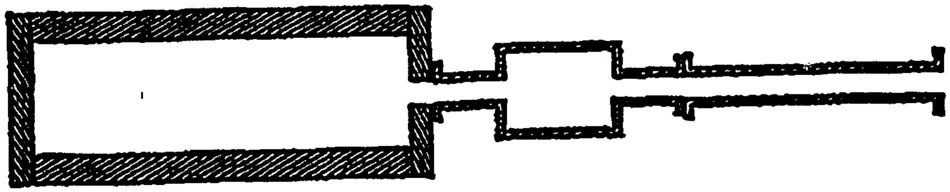
THREE SERIES OF SMALL-SCALE MODEL TESTS ARE BEING CONDUCTED BY WATERWAYS EXPERIMENT STATION AND THE AGENCY FOR DEFENSE DEVELOPMENT IN THE REPUBLIC OF KOREA. THE U.S. TESTING SHOULD BE COMPLETED THIS MONTH INVOLVING A TOTAL OF 120 TESTS. THIS WILL NOW BE FOLLOWED BY AN ANALYSIS OF THE TEST RESULTS.



a. Blast chamber and pipe (tunnel) components.



b. Assembly to investigate effect of tunnel lengths.

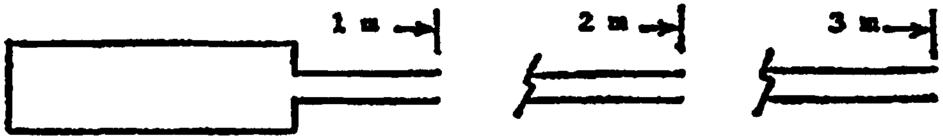


c. Assembly to investigate effect of an expansion chamber.

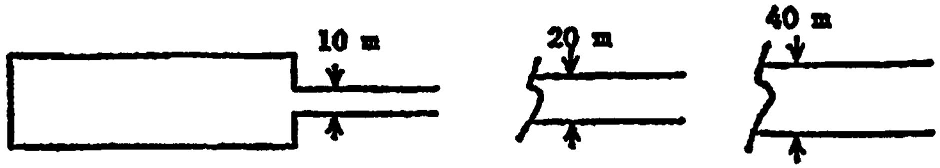
VUGRAPH 15

WATERWAYS EXPERIMENT STATION IS USING A STEEL DETONATION CHAMBER FABRICATED IN THE WATERWAYS EXPERIMENT STATION SHOPS. THE U.S. CHAMBER IS 2 METERS LONG WITH AN INTERNAL DIAMETER OF 50 CM AND A WALL THICKNESS OF 15.25 CM. THE CHAMBER VOLUME IS 0.365 M^3 (12.885 $FEET^3$).

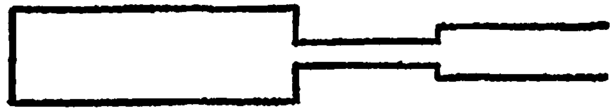
VARIOUS CONFIGURATIONS OF STEEL PIPE ARE ATTACHED TO THE DETONATION CHAMBER TO INVESTIGATE UNDERGROUND MAGAZINE DESIGN PARAMETERS.



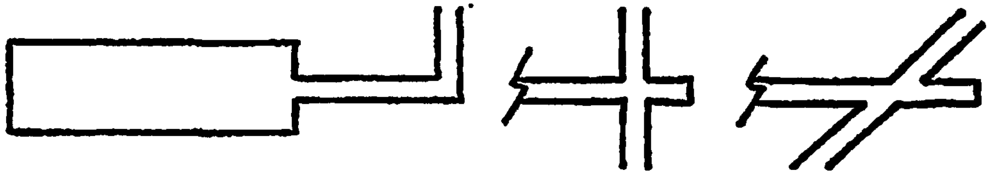
a. Effect of tunnel length.



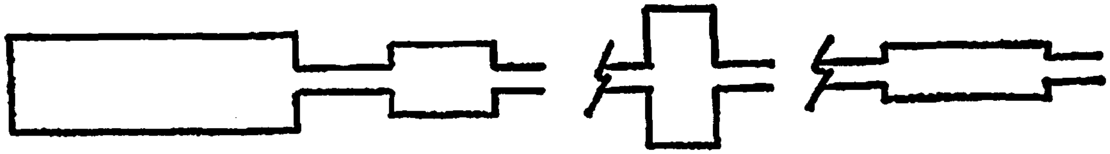
b. Effect of tunnel/chamber diameter ratios.



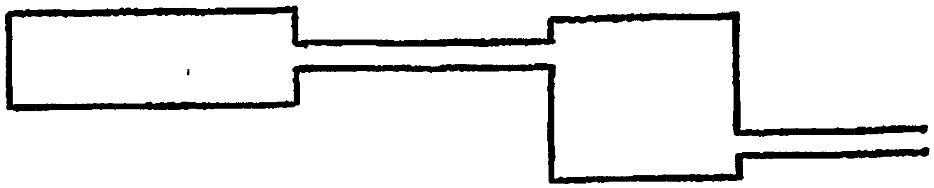
c. Effect of tunnel constrictions.



d. Effect of tunnel intersection geometries.



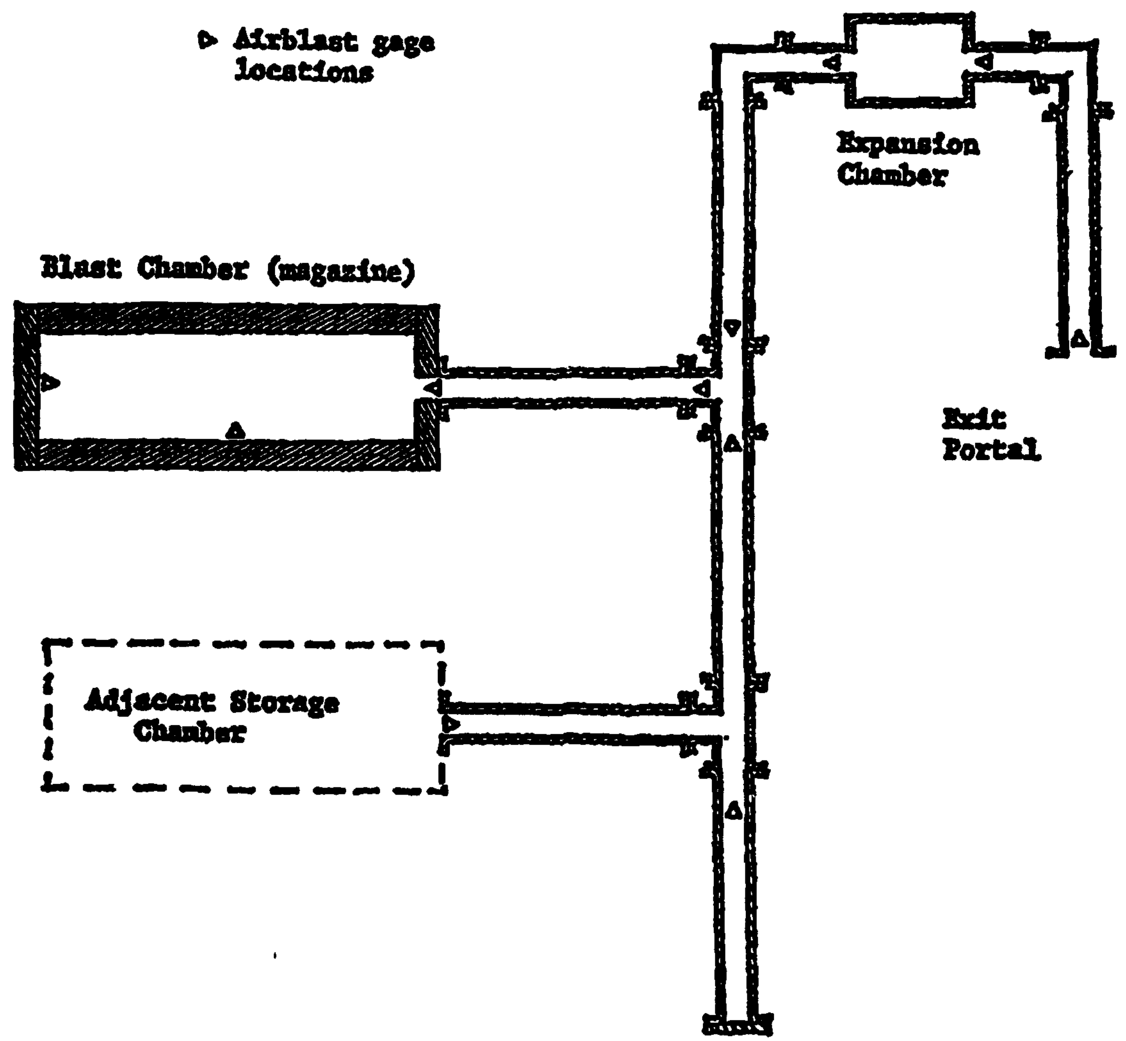
e. Effect of expansion chamber geometries.



f. Effect of offset expansion chamber exits.

VUGRAPH 16

THE GENERIC MODEL TESTS WILL EVALUATE THE EFFECTS OF; (1) TUNNEL LENGTH, (2) TUNNEL/CHAMBER DIAMETER RATIO, (3) TUNNEL VOLUME, (4) TUNNEL CONSTRICTIONS, (5) TUNNEL INTERSECTION GEOMETRY, (6) EXPANSION CHAMBER GEOMETRY, (7) MULTIPLE TUNNEL EXITS,


▷ Airblast gage locations
Blast Chamber (magazine)
Adjacent Storage Chamber
Expansion Chamber
Exit Portal

VUGRAPH 17

AND (8) COMPLEX TUNNEL LAYOUTS.

PHASE 2 SMALL-SCALE TEST PROGRAM

- CONSTRUCTION OF SMALL-SCALE TEST FACILITIES (U.S. AND ROK)
- CONDUCT SMALL-SCALE EXPLOSIVE TEST PROGRAM
- COMPUTER MODEL STUDIES OF CHAMBER/TUNNEL DESIGN PERFORMANCE
- EVALUATE RESULTS OF SMALL-SCALE TESTS AND COMPUTER MODEL STUDIES
- SELECT BEST DESIGN FEATURES FOR FURTHER STUDY

VUGRAPH 18

THE CHAMBER IS INSTRUMENTED FOR GAS PRESSURE, TEMPERATURE, AND THERMAL FLUX. GAS PRESSURE MEASUREMENTS ARE MADE WITH GAGES MOUNTED AT THE OUTER END OF THREE HOLES DRILLED THROUGH THE SIDE WALL OF THE CHAMBER AT POINTS 45 CM FROM EACH END AND AT THE MID-LENGTH. THERMAL GAGES (A THERMAL FLUX GAGE AND THERMOCOUPLE) ARE MOUNTED IN THE REAR WALL OF THE CHAMBER.

ADDITIONALLY WE ARE LOOKING AT:

- THE EFFECTIVENESS OF DEBRIS TRAPS AND BARRICADES FOR DETONATION DEBRIS CONTAINMENT.

- ALSO OPERATION AND EFFECTIVENESS OF TUNNEL CLOSURE SYSTEMS NEAR TUNNEL EXITS (LOW PRESSURE REGION) WILL BE STUDIED.

IN THE REPUBLIC OF KOREA, THE AGENCY FOR DEFENSE DEVELOPMENT HAS CONSTRUCTED FACILITIES ALSO. THE TESTS BY BOTH THE WATERWAYS EXPERIMENT STATION AND AGENCY FOR DEFENSE DEVELOPMENT ARE PLANNED TO COMPLEMENT EACH OTHER IN VERIFYING RESULTS. THE REPUBLIC OF KOREA PROGRAM RELATES TO A SIMILAR CHAMBER AND PIPING APPLICATION.

FOR INTERMEDIATE-TO-HIGH LOADING DENSITIES (20 TO 100 KG/M^3) THE PLANS ARE TO EVALUATE:

VUGRAPH 18 (CONT)

- THE EFFECT OF CHAMBER LOADING DENSITY ON TUNNEL ENTRY PRESSURES.
- THE EFFECT OF RATIOS OF CHAMBER CROSS-SECTION TO TUNNEL CROSS-SECTION, AND CHAMBER VOLUME TO TUNNEL CROSS-SECTION, ON TUNNEL ENTRY PRESSURES.
- THE CONTRIBUTION OF GAS PRESSURE "JETTING" ON EXTERNAL BLAST PRESSURES FROM DETONATIONS AT HIGH LOADING DENSITIES.
- THE EFFECT OF STEEP TOPOGRAPHIES FOR CONTROLLING EXTERNAL BLAST EFFECTS.
- THE EFFECT OF CHAMBER SPACINGS (IN ROCK) ON DAMAGE TO "ACCEPTOR" CHAMBERS.
- THE EFFECTIVENESS OF "SELF-SEALING" CHAMBER DESIGNS AND BLAST-ACTIVATED CHAMBER PLUGS FOR CONTAINMENT OF BLAST PRESSURES IN THE HIGH-PRESSURE REGION.

COMPUTER MODEL STUDIES ARE ON-GOING IN THE U.S. AND REPUBLIC OF KOREA:

THIS INCLUDES IN THE U.S. THE:

- INVESTIGATION OF CHAMBER SELF-SEALING CONCEPTS WITH THE UNIVERSAL DISCRETE ELEMENT CODE.
- DETERMINING MINIMUM ROCK COVER DEPTHS OVER CHAMBERS FOR DETONATIONS OF DIFFERENT LOADING DENSITIES, FOR DIFFERENT ROCK PROPERTIES, USING SHARC.
- DETERMINING DEBRIS EJECTION VELOCITIES FROM CHAMBERS AND ACCESS TUNNELS,

VUGRAPH 18 (CONT)

EVALUATING DEBRIS CONTROL WITH BLAST TRAPS (IN TUNNELS) AND EXTERNAL BARRICADES, USING SHARC AND UNIVERSAL DISCRETE ELEMENT CODE.

- ALSO DETERMINING DYNAMIC GAS FLOW PRESSURE HISTORIES FOR ACTIVATION OF TUNNEL CLOSURE SYSTEMS.

- CALCULATING STRESS LOADS TRANSMITTED THROUGH ROCK TO "ACCEPTOR" CHAMBERS FROM "DONOR" CHAMBER DETONATIONS, AS FUNCTION OF ROCK TYPES AND CHAMBER SPACINGS.

ALSO IN THE REPUBLIC OF KOREA THEY ARE:

- DETERMINING PRESSURE HISTORIES AS FUNCTION OF LOADING DENSITIES, TUNNEL LENGTHS, AND TUNNEL LAYOUT GEOMETRIES, USING HULL AND SHARC CODES.

- ALSO, DETERMINING TUNNEL PRESSURE REDUCTIONS FROM EXPANSION CHAMBERS AND TUNNEL CONSTRICTIONS, USING HULL AND SHARC CODES.

PHASE 2 TESTING IN THE U.S. IS EXPECTED TO BE COMPLETED THIS MONTH. THE REPUBLIC OF KOREA EFFORT MAY CONTINUE A FEW MONTHS.

BASED ON THE EVALUATIONS BY EACH LEAD LAB (AGENCY FOR DEFENSE DEVELOPMENT AND WATERWAYS EXPERIMENT STATION) AND THE RECOMMENDATIONS OF THE TECHNICAL ADVISORY GROUPS, THE U.S. AND REPUBLIC OF KOREA TECHNICAL PROGRAM MANAGERS

VUGRAPH 18 (CONT)

WILL IDENTIFY THE MOST PROMISING DESIGN FEATURES (OF THOSE INVESTIGATED IN PHASE 2) FOR FURTHER INVESTIGATION IN PHASE 3.

PHASE 3 INTERMEDIATE-SCALE TEST PROGRAM

- DESIGN WILL BE A DIRECT RESULT OF PHASE 2 TESTING PROGRAM
  - U.S. IS PLANNING TO USE EXISTING MINES WITH MODIFICATIONS IN NEW MEXICO
  - ROK HAS SELECTED A TEST SITE "DARAKDAE" NORTH OF SEOUL

<u>NARRATIVE PHASE 3</u>

VUGRAPH 19

THE TEST OBJECTIVES AND TEST PLANS FOR 1/5- AND 1/3-SCALE INTERMEDIATE EXPLOSIVE TESTS VARY FROM 10 KG TO 2,000 KG. FURTHER COMPUTER MODEL STUDIES WILL BE DEFINED FOR EACH SIDE'S CONTRIBUTION TO PHASE 3 OF THIS JOINT RESEARCH AND DEVELOPMENT PROGRAM. TESTING IS PLANNED TO BEGIN IN SUMMER 1993.

U.S. INTERMEDIATE-SCALE TEST SITE. THE U.S. TECHNICAL MANAGER HAS LOCATED A SITE NEAR MAGDALENA (SOCORRO COUNTY), NEW MEXICO, THAT FULLY MEETS PLANNED TEST REQUIREMENTS. THE SITE IS A PRIVATELY-OWNED MINING COMPLEX, CONTAINING TWO TUNNELS, NAMED LINCHBURG AND PATTERSON MINES. THE TWO TUNNELS ARE SEPARATED BY A FEW HUNDRED METERS AND ARE JOINED AT THE REAR BY A LARGE, CAVERNOUS EXCAVATION. THE MINE IS CURRENTLY INACTIVE. THE TUNNELS ARE FAIRLY STRAIGHT, 2 METERS WIDE, 2 METERS HIGH, AND APPROXIMATELY 1,000 METERS LONG. THE GEOLOGY OF THE MINE COMPLEX INDICATES COMPETENT ROCK THROUGHOUT, ALLOWING THE EXCAVATION OF UNDERGROUND TEST CHAMBERS UP TO 5 METERS WIDE AND 3 METERS HIGH WITH A MINIMUM OF ROCK BOLTING OR OTHER REINFORCEMENT. THE TOPOGRAPHY IN THE VICINITY OF THE TUNNEL ENTRANCES, WITH A LARGE HILL ACROSS FROM A SMALL CANYON, WILL PROVIDE OPPORTUNITIES TO MEASURE EXTERNAL BLAST OVER MOUNTAINOUS TERRAIN. (THE U.S. HAS RECENTLY SECURED A ONE-YEAR LEASE ON THIS PROPERTY.)

VUGRAPH 19 (CONT)

REPUBLIC OF KOREA INTERMEDIATE-SCALE TEST SITE. THE REPUBLIC OF KOREA TECHNICAL MANAGER HAS SELECTED DARAKDAE, NORTH OF SEOUL, AS THEIR PHASE 3 INTERMEDIATE-SCALE TEST SITE. THE SITE CONSISTS OF A STEEP RIDGE INTO WHICH TEST CHAMBERS CAN BE BORED OR EXCAVATED FACING INTO A HILLSIDE ACROSS A NARROW, 100-METER WIDE VALLEY. THIS SITE IS REPRESENTATIVE OF TYPICAL KOREA TOPOGRAPHY.

EXPECTED RESULTS

- SOLUTION TO AMMUNITION STORAGE SAFETY PROBLEM IN KOREA (UNDERGROUND STORAGE)
  - ALLOW CONFORMANCE WITH THE STANDARDS, REMOVING THOUSANDS OF U.S./ROK MILITARY AND CIVILIANS FROM RISK
- SOLUTION WILL ALSO PROVIDE BONUS BENEFITS:
  - APPLICABLE WORLDWIDE TO MANY U.S. ARMY NAVY, USAF SITES
    - -- MUCH GREATER SECURITY
    - -- MAJOR IMPROVEMENT IN SURVIVABILITY
    - -- ASSURED LONG-TERM COST SAVINGS

VUGRAPH 20

THIS PROGRAM WILL PROVIDE APPLICATIONS FAR BEYOND OUR AMMUNITION STORAGE IN KOREA. ALL OF OUR PAST STORAGE APPLICATIONS AND EXPLOSIVES TESTING CONDUCTED WITHIN THE DEPARTMENT OF DEFENSE, AND THE EUROPEAN COMMUNITY AS WELL, SUPPORTS THE EXPLOSION EFFECTS EXPERTS' CONSIDERATIONS THAT NEW UNDERGROUND STORAGE CONCEPT DESIGNS HAVE THE POTENTIAL TO SOLVE THE EXPLOSION PROBLEMS; AID IN BETTER SECURITY; PROVIDE FOR AMMUNITION SURVIVABILITY; AND RELATE TO COST SAVINGS BY REDUCING THE NEED FOR VALUABLE REAL ESTATE TO SATISFY SAFETY BUFFER ZONES, AS I MENTIONED IN THE BEGINNING. IT WILL ALSO REDUCE ASSOCIATED FACILITY COST INVESTMENT AND GAIN LONG-TERM SAVINGS.

CONCLUSION

- JOINT ROK/U.S. R&D PROGRAM TO PROVIDE NEW DESIGN CONCEPTS IS WELL UNDERWAY
- PHASE 2, SMALL-SCALE TESTING IS NEARING COMPLETION
- PHASE 3, INTERMEDIATE-SCALE TESTING IS BEING PLANNED
- PROGRESS TO DATE HAS BEEN EXCELLENT AND IS EXPECTED TO CONTINUE.

VUGRAPH 21

IN CONCLUSION - THIS JOINT RESEARCH AND DEVELOPMENT EFFORT IS EXPECTED TO RESOLVE MANY OF THE QUESTIONABLE TECHNICAL AREAS SUCH AS EXPLOSION CONTAINMENT, DEBRIS THROW, BLAST OVERPRESSURE MEASUREMENT, AND PREDICTIONS AND GROUND SHOCK APPLICATIONS. THE PROGRAM IS WELL UNDERWAY.

PLANNING, AS I INDICATED, FOR THE INTERMEDIATE-SCALE TESTING IS ON-GOING. BOTH THE U.S. AND REPUBLIC OF KOREA TECHNICAL MANAGERS HAVE VISITED THE U.S. INTERMEDIATE-SCALE TEST SITE.

WE ARE EXCITED ABOUT OUR JOINT EFFORTS AND FULLY EXPECT GOOD RESULTS WHICH CAN BE SHARED WITH THE ENTIRE EXPLOSIVES SAFETY COMMUNITY. THE SUCCESS OF OUR FIRST THREE TECHNICAL ADVISORY GROUP MEETINGS SUPPORTS OUR CONTENTION THAT WE ARE PROGRESSING WELL.

THANK YOU!

Naval Surface Warfare Center
DAHLGREN DIVISION

TRIALS TO DETERMINE THE EFFECTS OF THE ACCIDENTAL IGNITION OF STACKS OF HAZARD DIVISION 1.2 AMMUNITION

M. J. A. Gould

UK Ministry of Defence
Explosives Storage and Transport Committee

and

W. D. Houchins K. W. Rye M. M. Swisdak

U. S. Naval Surface Warfare Center/Dahlgren Division

HD1.2 AMMUNITION TRIALS

BACKGROUND

- To date most work aimed at characterizing HD1.1 effects
- 1989 NATO AC258 agreed program of trials to be conducted on HD1.2 effects
- UK/US agreed to finance trials to enable them to proceed promptly
- Opportunity to reconcile US, UK and NATO approach to quantity-distances

HD1.2 AMMUNITION TRIALS

Naval Surface Warfare Center DAHLGREN DIVISION

CURRENT HD1.2 Q-D RULES

- US
  - Inhabited Building Distances (IBD's) fixed
    - Independent of quantity
    - Based on maximum fragment range observed in small bonfire tests
  - Other distances are fixed or fractions of IBD

- UK/NATO
  - IBDs based on quantity
    - $D = 53Q^{0.18}$ or $68Q^{0.18}$
    - Believed to be based on fragment density
  - Other distances fixed or fractions of IBD

HD1.2 AMMUNITION TRIALS

PROGRAM

➡ *Two Parts:*

- **Part 1. Trials on exposed stacks of ammunition**
- **Part 2. Trials on stacks of ammunition inside structures**

HD1.2 AMMUNITION TRIALS

OBJECTIVES

Part I

- To determine the effects of fires involving open stacks of HD1.2 ammunition
- To determine the relationship(s) between stack size and effects
- To establish a data base for evaluating existing quantity-distance rules for HD1.2 ammunition
- To develop proposals for revised quantity-distance relationships for HD1.2 ammunition

HD1.2 AMMUNITION TRIALS

OBJECTIVES

Part II

- To determine the influence that typical storage structures will have on HD1.2 events

- To develop further proposals for quantity-distances based on trials results

HD1.2 AMMUNITION TRIALS

TEST PROGRAM

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DAHLGREN DIVISION

Part I

- Six tests using 105mm artillery cartridges
  - Three 1-pallet tests
  - Two 8-pallet tests
  - One 27-pallet test
- At least one test using different caliber and type of ammunition

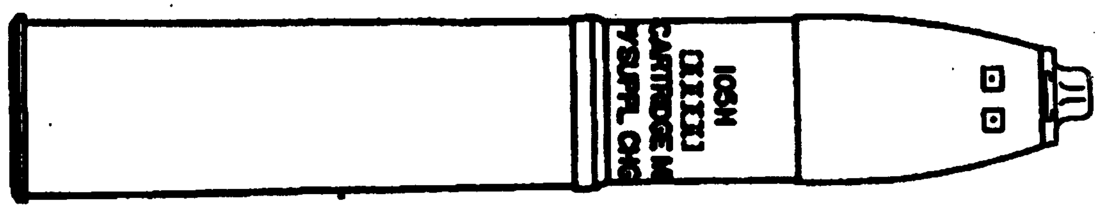
HD1.2 AMMUNITION TRIALS

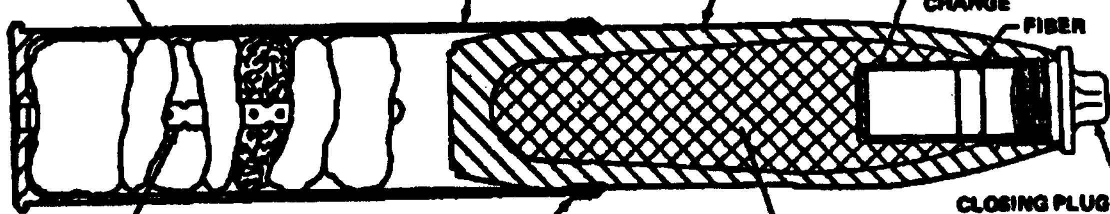
TEST ITEMS

➡ M1 105mm HE artillery cartridge

- Semi-fixed round
- Approximately 4 1/2 lb. TNT (projectile fill)
- Approximately 3 lb. M1 propellant (propelling charge)
- Aluminum closure plug in lieu of nose fuze
- 2 cartridges per wooden box
- 15 or 16 boxes per pallet

M1 105mm CARTRIDGE

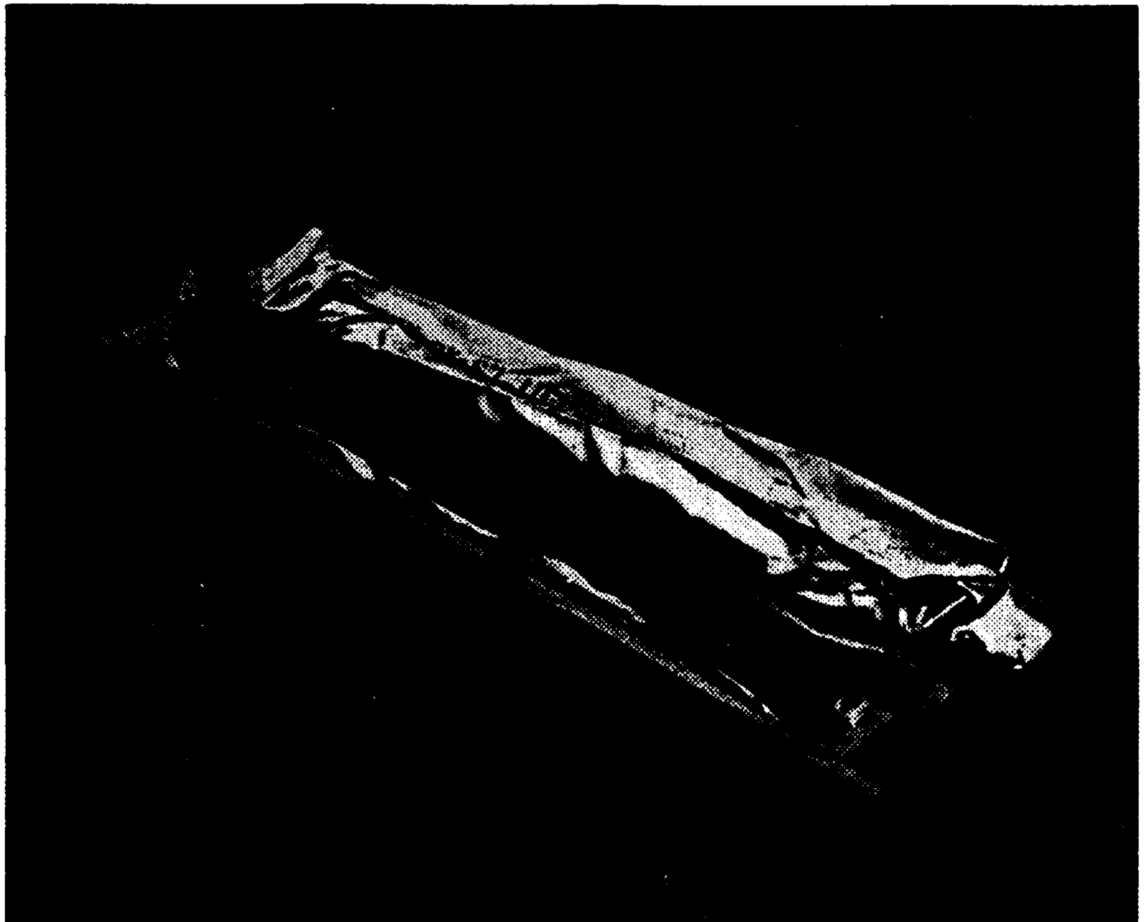




Projectile Fill:	**4.5 lb TNT (approx)**
Propelling Charge:	**3 lb M1 propellant (approx)**

HD1.2 AMMUNITION TRIALS

PACKAGING OF M1 105mm CARTRIDGES



TEST METHOD

➡ **BONFIRE**

- Generally meeting requirements of UN "Orange Book", Test 6

➡ **MEASUREMENTS**

- Fragment recovery over 360 deg and out to 2000 ft
- Blast overpressure at 50, 70, 100, and 200 ft
- Shuttered video recording

HD1.2 AMMUNITION TRIALS

SETUP FOR SINGLE PALLET AND FIRST 8-PALLET TESTS

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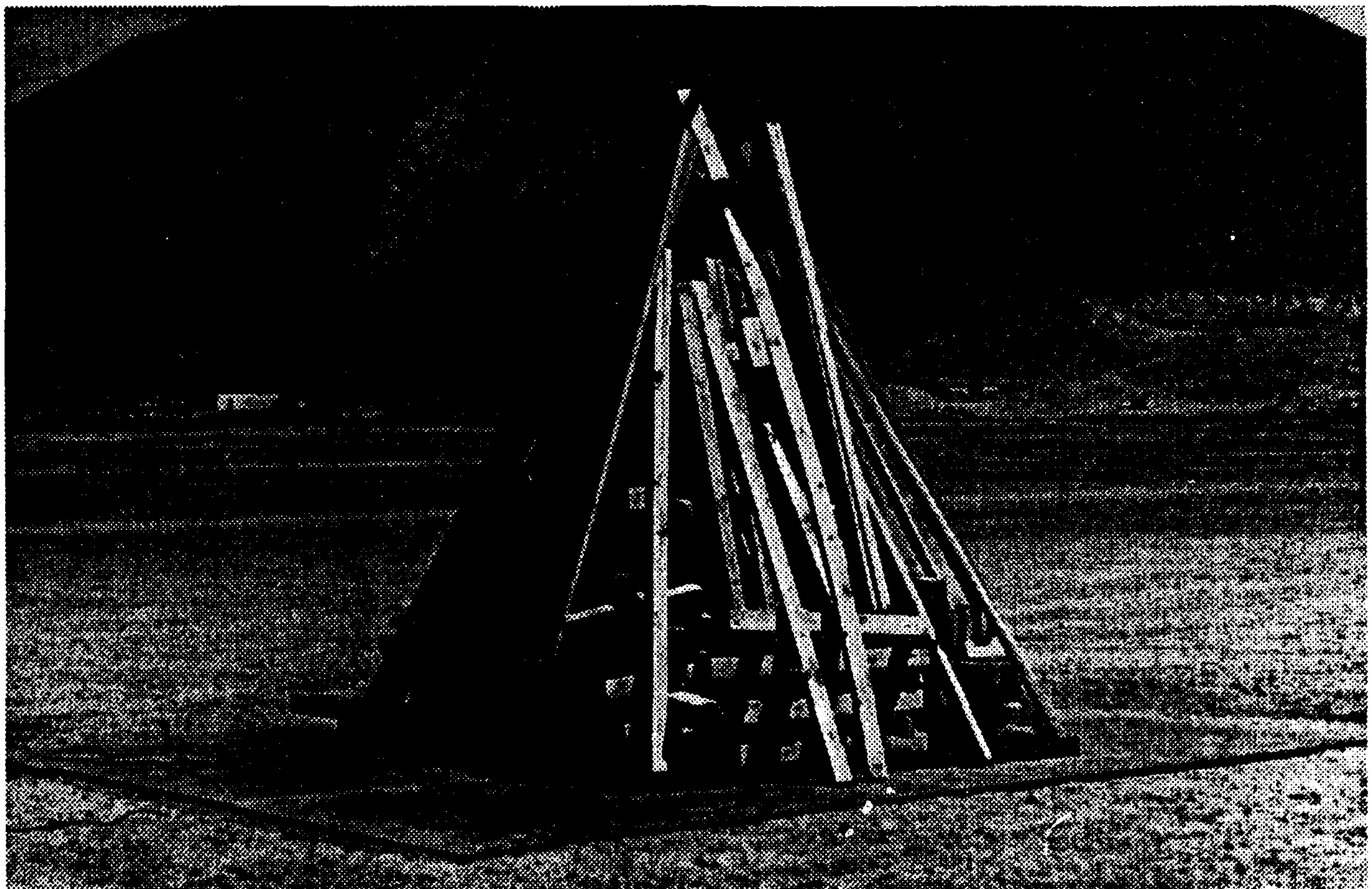

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HD1.2 AMMUNITION TRIALS
SETUP FOR SECOND 8-PALLET TEST

HD1.2 AMMUNITION TRIALS
RECOVERY AREA

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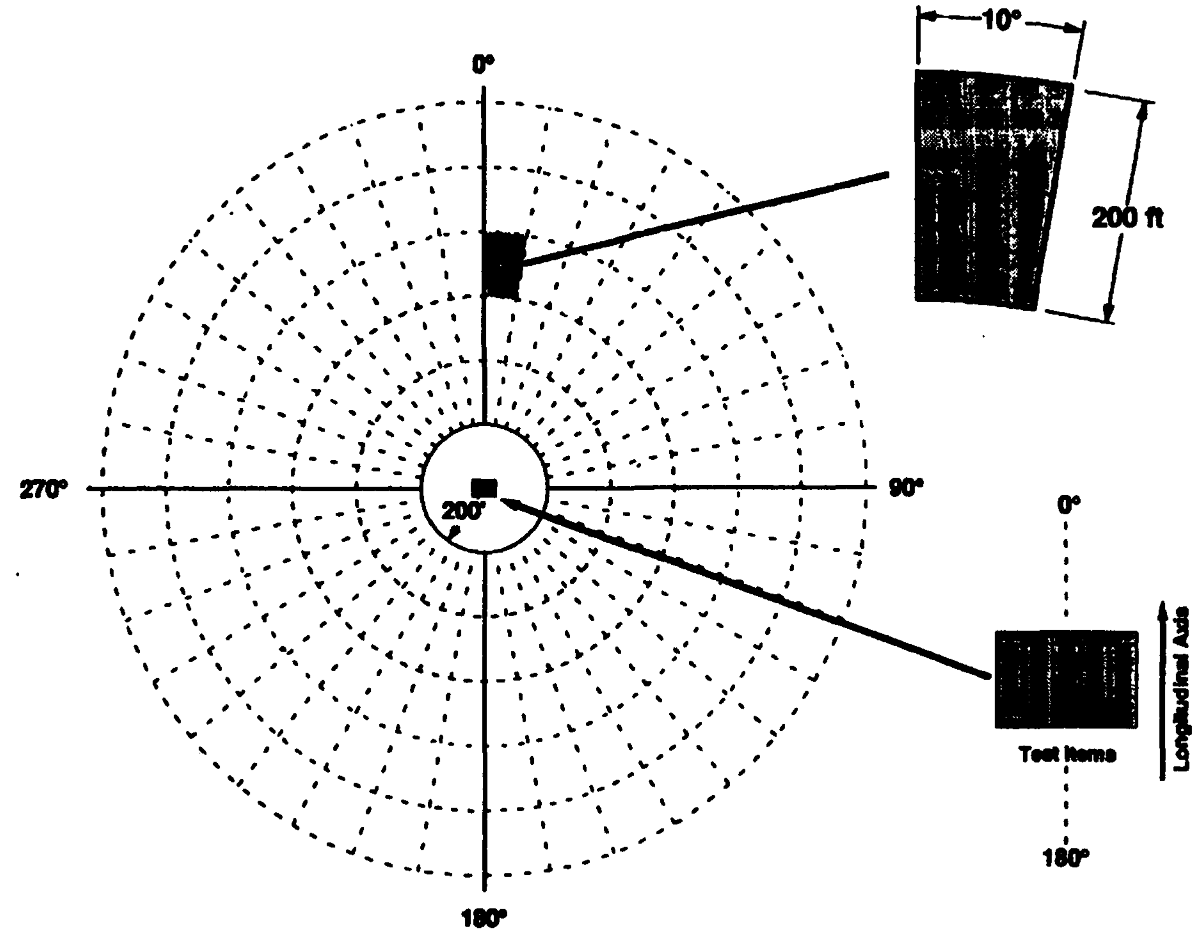

HD1.2 AMMUNITION TRIALS

GENERAL OBSERVATIONS

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Test Nos. 1 - 6

Test No.	No. of Pallets (No. of Cartridges)	Approximate Event Times	No. of Major Reactions*	No. of Projectiles Recovered Intact
1	1 (30)	15:30 ➡ 49:00	13	17
2	1 (30)	20:20 ➡ 42:35	9	21
3	1 (30)	20:05 ➡ 78:40	11	18**
4	8 (240)	18:10 ➡ 61:00	66	174
5	8 (240)	14:15 ➡ 41:15	65	174
6	27 (864)	21:10 ➡ 73:35	289 ≤ No. ≤ 318	546

* Believed to be explosion or detonation of projectile(s)

** A 19th projectile was recovered nearly intact (case breached)

HD1.2 AMMUNITION TRIALS

TEST NO. 6 AFTERMATH

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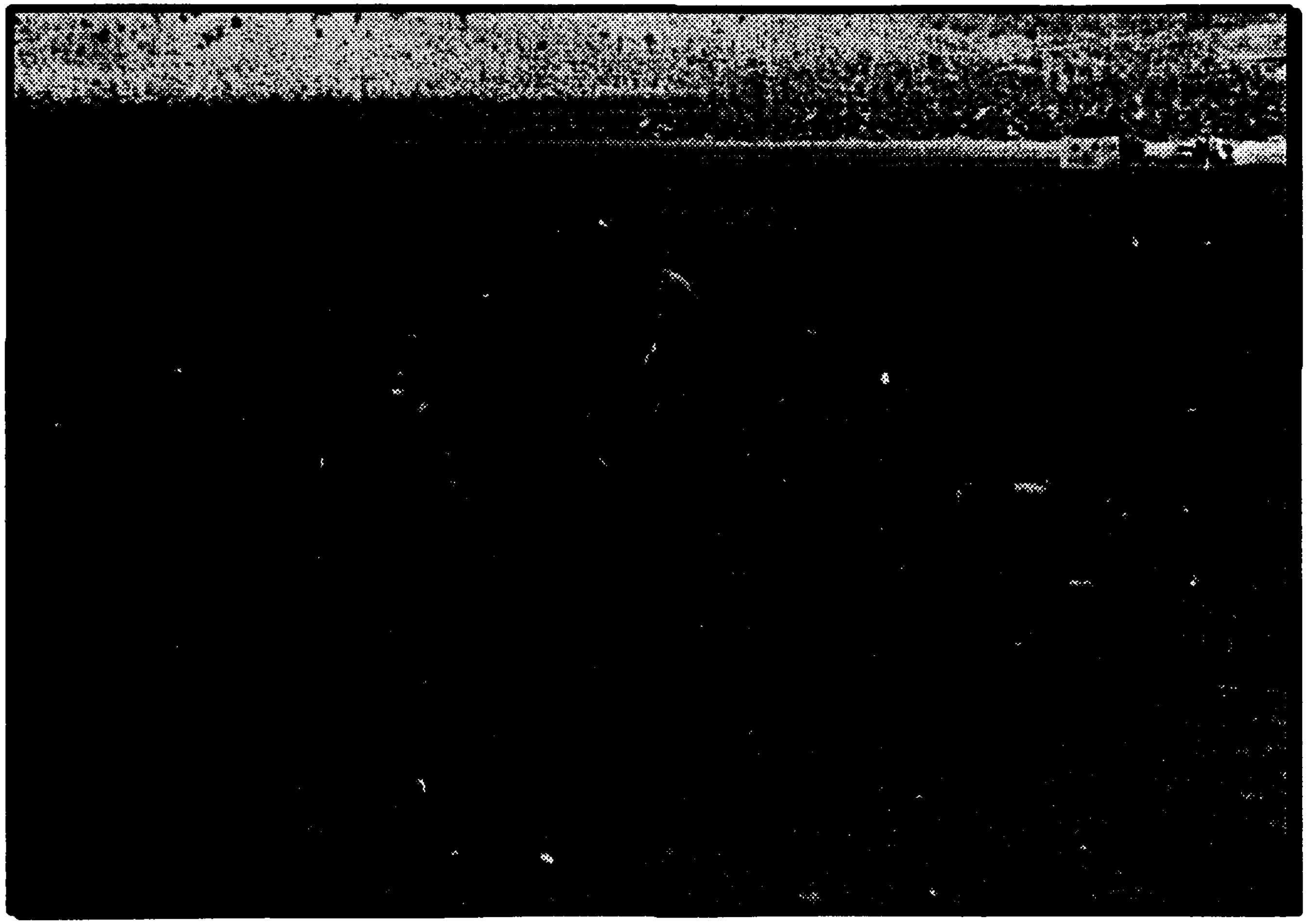
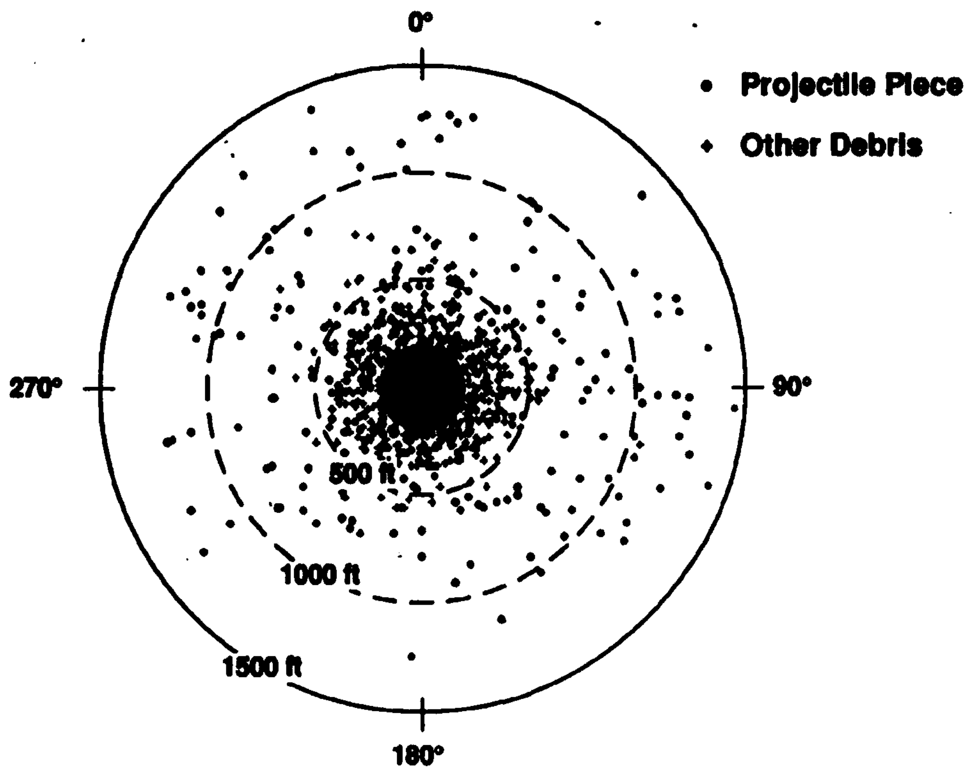


HD1.2 AMMUNITION TRIALS

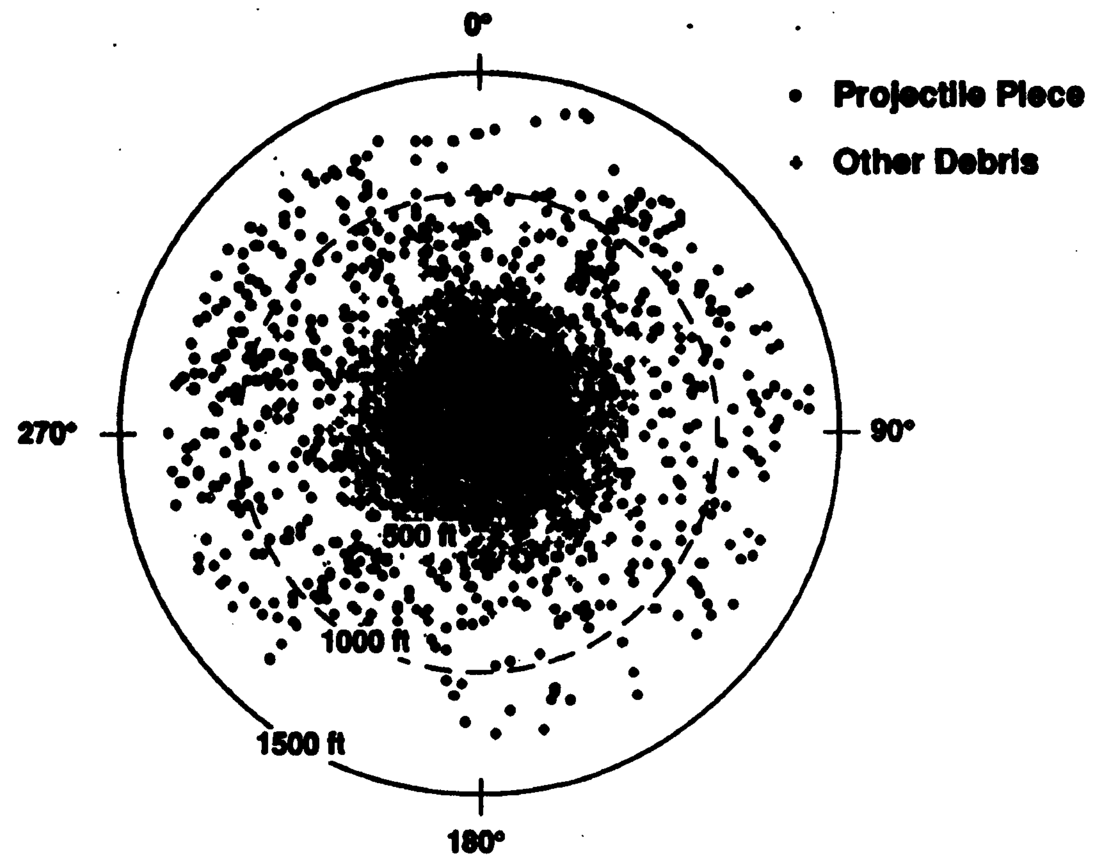
8-PALLET TEST RESULTS

Approximate Distribution of Far-Field Fragments for 1st 8-Pallet Test (Test No. 4 of Series)



HD1.2 AMMUNITION TRIALS
27-PALLET TEST RESULTS

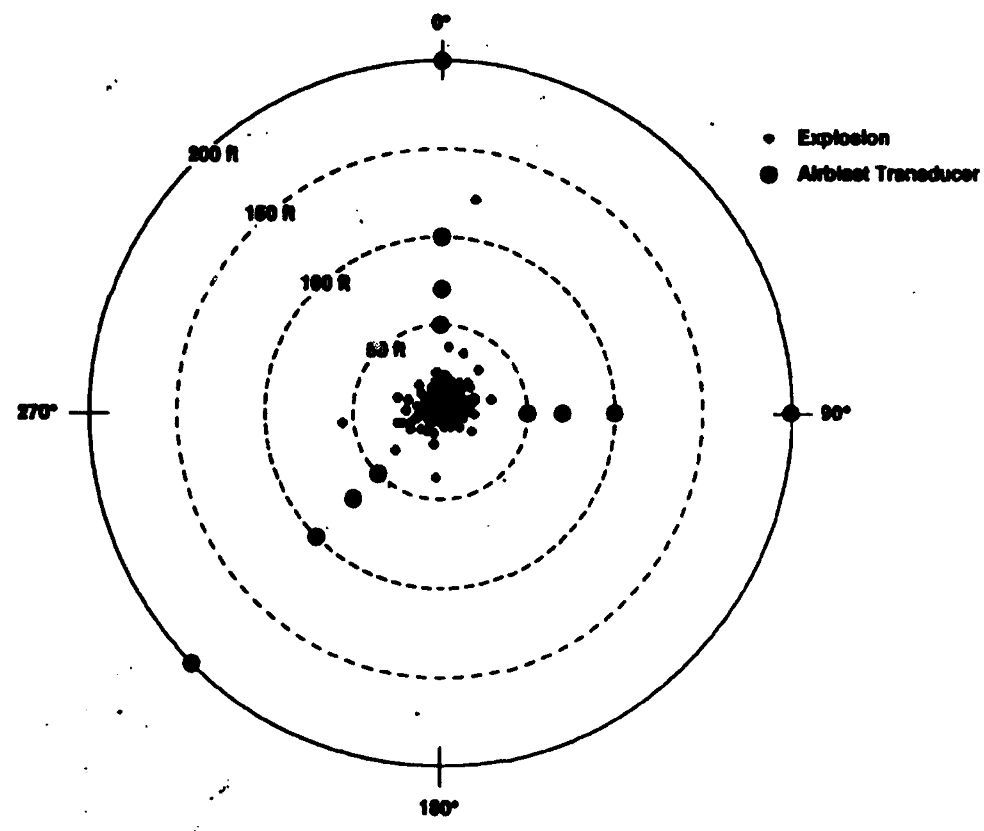
Approximate Distribution of Far-Field Fragments



HD1.2 AMMUNITION TRIALS

27-PALLET TEST RESULTS

Approximate Locations of Projectile Explosions Based on Blast Data

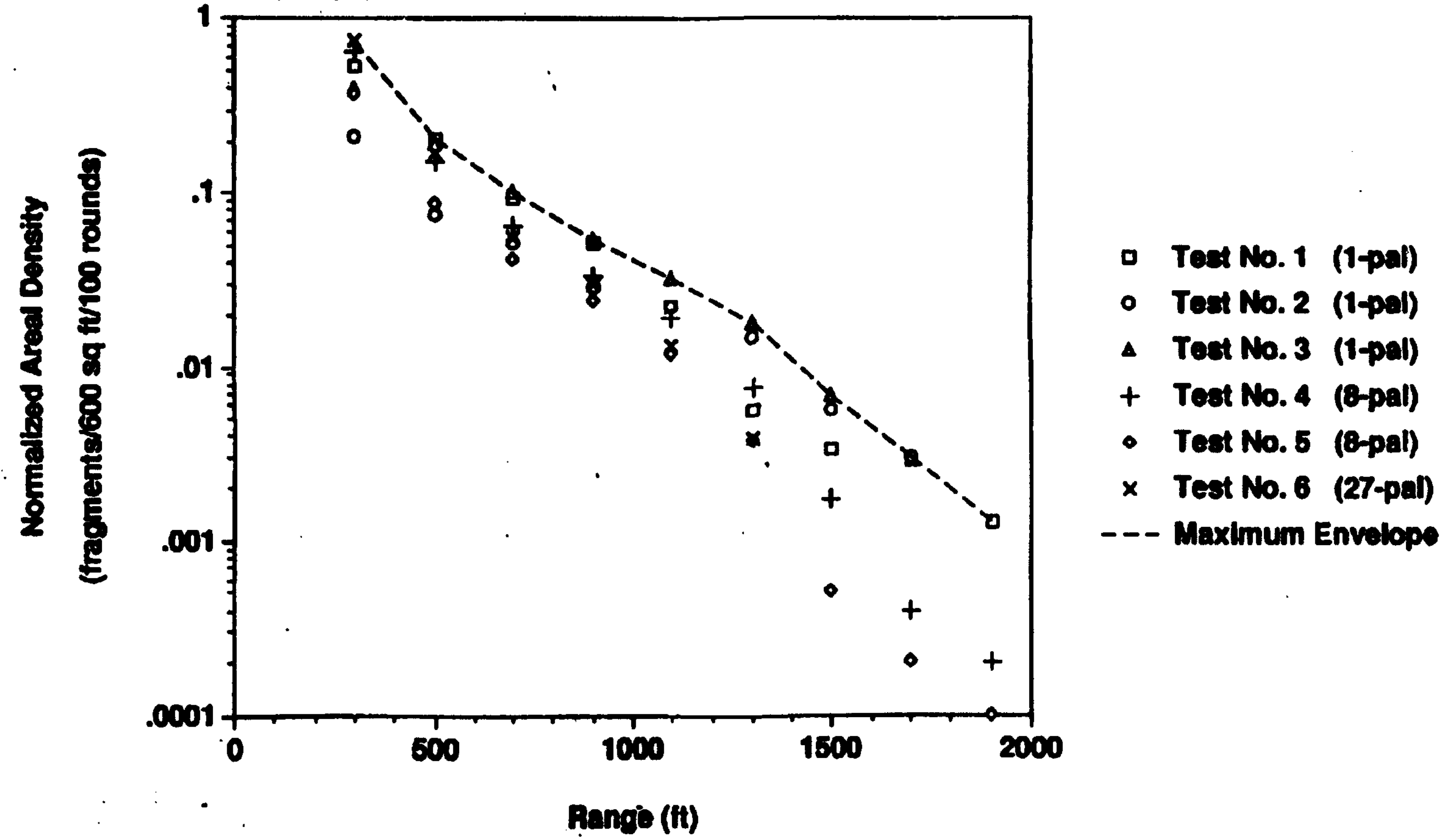


HD1.2 AMMUNITION TRIALS
ANALYSIS METHOD

- ➡ Calculate areal densities of fragments vs range
  - Assume azimuthal distribution is random
  - Assume all fragments are hazardous (i.e., <58 ft-lb KE)
  - Fragment counts scaled based on estimated % recovery
  - Densities based on pseudo-trajectory-normal methods
- ➡ Extrapolate to larger stack sizes
  - Use highest normalized densities observed for each range increment (i.e., maximum envelope of test results)
- ➡ Estimate range to exceed HD1.1 criterion for fragment density (1/600 ft^2)

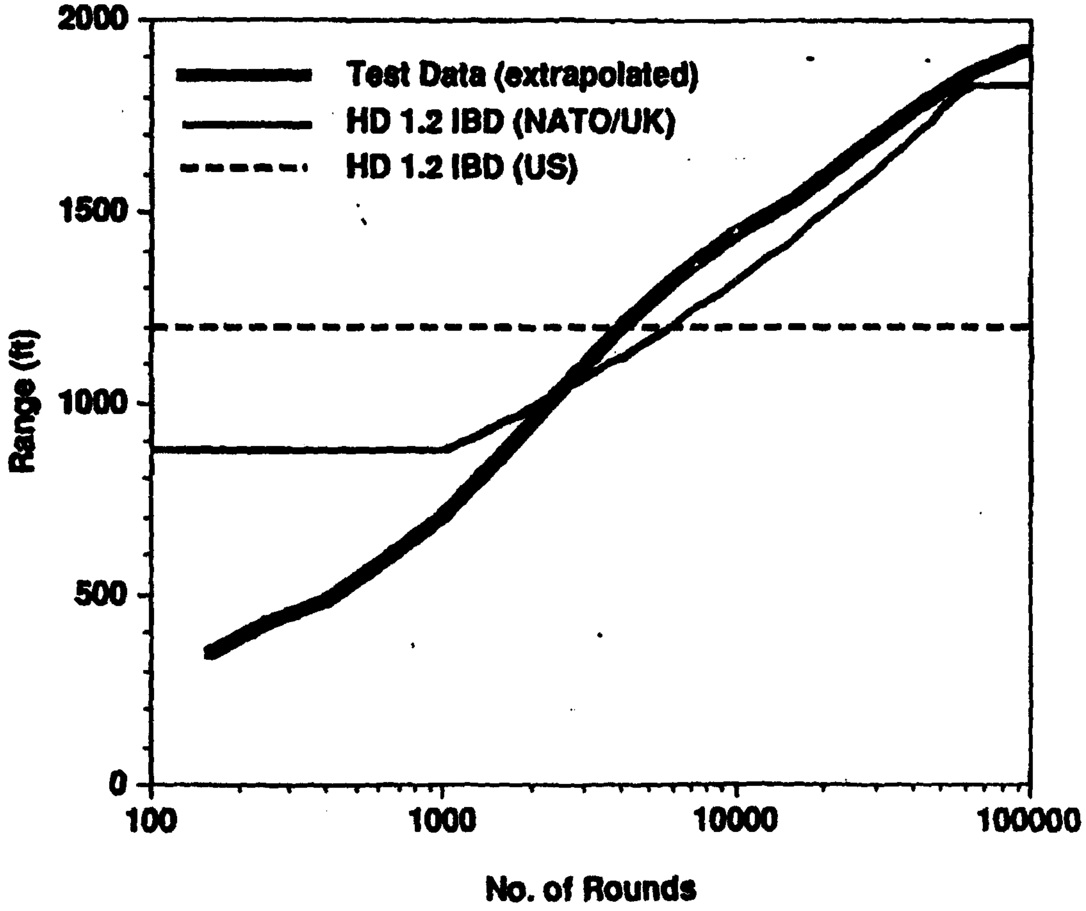
HD1.2 AMMUNITION TRIALS

NORMALIZED FRAGMENT DENSITIES



HD1.2 AMMUNITION TRIALS

ESTIMATED RANGE TO EXCEED 1 FRAGMENT/600 FT²
VERSUS CURRENT HD1.2 Q-D REQUIREMENTS



HD1.2 AMMUNITION TRIALS
INDICATIONS

- Bonfire results in progressive explosion of $\approx$ $^1/_3$ of projectiles
  - Reactions begin $\approx$ 15 min after ignition; entire event lasts $\approx$ 1 hour
  - Consistent for stack sizes tested
- Most explosions produces a small number of relatively large fragments
- Most explosions occur in immediate vicinity of fire
  - Muntion lob does not contribute significantly to fragment ranges
- Fragment distribution is random azimuthally; density decreases rapidly with range
  - Projectile case fragments are primary contributor to far-field fragment hazard
- Current HD1.2 Q-D's appear to be conservative for small stack sizes

HD1.2 AMMUNITION TRIALS

FUTURE PROGRAM

➡ Additional test using different type and caliber munition	1994
➡ Part 2 program (structures)	1994 +